Vulnerability, Consequences, and Adaptation
Planning Scenarios (VCAPS)

Town of Carbondale

Final Workshop Report

Submitted by:

Western Water Assessment
Cooperative Institute for Research in Environmental Sciences
University of Colorado Boulder

About the Western Water Assessment

Western Water Assessment (WWA) is a university-based applied research program that addresses societal vulnerabilities to climate variability and climate change, particularly those related to water resources. While we are based in Boulder, Colorado and Salt Lake City, Utah, we work across the Colorado, Utah, and Wyoming. Our mission is to conduct innovative research in partnership with decision makers, helping them make the best use of science to manage for climate impacts. WWA is part of the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder. Our primary source of funding is NOAA's Regional Integrated Sciences and Assessments (RISA) Program, and we are one of 11 RISA teams operating across the United States.

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Note

This material is based upon work supported by the National Oceanic and Atmospheric Administration (NOAA). Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of NOAA.

Table of Contents :

1. Executive Summary: Preparing for Drought in Carbondale, Vulnerability, Consequence, and Adaptation Planning Scenarios, Key finding and discussions:

Introduction and Purpose

On September 26-27, 2018, the town of Carbondale participated in a Vulnerability, Consequences, and Adaptation Planning Scenarios (VCAPS) workshop. The VCAPS approach uses facilitated discussion to support municipalities in building resilience towards weather and climate hazard and impacts. Carbondale's key concern for this workshop was the issue of drought.

Local Weather and Climate Trends

- *Precipitation:* Even with the most recent severe droughts, there is no clear trend in precipitation; the average precipitation since 2000 is about the same as the average over the 20th century. For water year 2018 (October-September), precipitation was slightly below normal in Carbondale, but much lower than normal in the higher elevations of the Roaring Fork Valley where the flows of the Roaring Fork River and Crystal River originate.
- *Temperatures:* There has been a strong upward trend in temperatures over the past 40 years that stands out from the year-to-year natural variability (Figure 2). The average temperature since 2000 has been 2.2°F higher than the 20th-century average, with 4 of the 5 warmest years coming in the 21st century: 2000, 2012, 2017, and 2018.

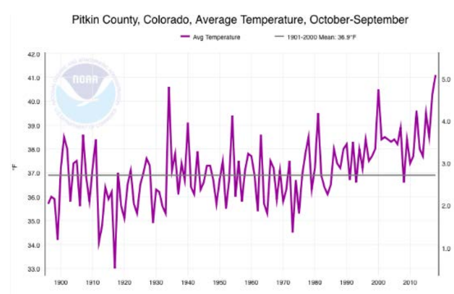

Figure 1 Annual (water-year) average temperature for Pitkin County, 1896-2018. Temperatures since 2000 have been over 2°F warmer than the 20th-century average, and 2018 was the warmest water year on record. (Source: NOAA NCEI;

- *Snowpack and streamflow:* The vast majority (70-85%) of the streamflow in the Roaring Fork originates as melting snow; the snowpack acts an enormous seasonal reservoir that accumulates water during the cold season (October-May) and releases it during the spring runoff season. Since 2000, Roaring Fork streamflow's have been about 13% lower than the 20th-century average, in contrast with the Routt County precipitation record, which shows no decline since 2000.
- *Future climate trends:* All climate models indicate that the climate of the Roaring Fork Valley will continue to warm well into the 21st century. Under the lower-emissions scenario, by 2050, average temperatures are projected to be 3-5°F warmer than the late-20th century average, and 3-7°F warmer by 2080. Under the higher-emissions scenario, the warming would be even larger, with temperatures 4-6°F warmer by 2050 and 7-11°F warmer by 2080. Hydrology projections show that April 1 Snow-Water Equivalent (SWE) for western Colorado and the Roaring Fork will decline by 2050 by 5-20%, due mainly to the effects of warming. With warmer temperatures and declining snowpacks the projections also show that annual streamflows in western Colorado are likely to decrease by 2050, by as much as 20 to 30%.
- *Future drought and wildfires:* Extreme drought events like 2002 and 2018 will occur more frequently than in the 20th century, and drought conditions, once established, are likely to persist longer. The fire season will become longer, fire severity will increase, and the annual area burned by wildfires across Colorado will increase significantly by mid-century.

Discussions themes during the diagraming exercises and cross-cutting themes:

During the discussions for the diagraming exercise, in which participants mapped out the causal structure of a 2018-type drought and then a multi-year severe drought, multiple themes occurred. For the 2018-type drought the conversation was centered around these nine themes:

(i) Reduced runoff, (ii) Stress on ecosystems, (iii) Fires, (iv) Reduced water supply, (v) More concentrated solids in waste water, (vi) Tourism, (vii) Reduced irrigation for town facilities, (viii) Reduced water for agricultural irrigation out of town, (ix) Call on the Nettle Creek
For the multi-year severe drought three themes emerged: (i) Stress on Ecosystems, (ii) Increased Fire Risk, (iii) Tourism.

During these exercises multiple cross-cutting themes appeared. These themes are important to the context of Carbondale and give an overview of challenges, opportunity, outcomes and actions:

- *Education*: Educating the public came up multiple times in actions proposed by the group to mitigate different impacts of drought. The belief was that giving the public more information related to key consequences of drought, would help mitigate conflicts between residents with different interests, and gain more acceptance for public actions, such as town water restrictions.
- *Facilitating dialogues*: Facilitating communication and dialogues between residents was seen by the group as applicable to multiple issues. Facilitating discussions among the town's residents could help reconcile the different expectations that the residents have towards local amenities and services.
- *NGOs*: NGOs such as CLEER, the Aspen Valley Land Trust, and others were often cited as being important actors in the town and valley and a valuable resource during droughts. NGOs could help facilitate dialogues with the population, create marketing campaigns related to water restrictions and help better educate citizens about drought and its effects. The NGOs present in town can be pivotal partners when facing drought, potentially helping to bridge the gap among different perspectives.
- *Disparities among residents in opinions and wealth*: There are strong division in opinions about water management in town. Different sectors and residents need water for various reasons (e.g., ranching, guided fishing) and competition for water use may occur between different actors. Wealth inequality is also a major contextual factor for the town. Very wealthy residents and working-class residents are part of the same community, but do not face the same challenges and do not have the same influence over water use and public water issues.
- *Valuing the mountain town character*: The attractive municipal parks and the multiple green spaces give a very lush sensation to the town although they become threatened in times of drought, which may become more frequent in the future. Proposed ideas included using more drought-resistant plants, creating nurseries for xeriscaping plants and reviewing the right sizing of landscaping.
- *Farming and ranching heritage*: Surrounding Carbondale is a strong farming and ranching community which helps shape the town's identity. Nevertheless, this community is very exposed to the changes in water regimes and thus, during severe drought periods, can be particularly vulnerable. It is crucial for Carbondale to work closely with the farming and ranching community and assist business and NGOs that support and sustain this community during drought periods. Participants also suggested workshops between town residents and the surrounding agricultural community to build shared understanding around water.
- *Town management:* Participants often referred to changing town management practices as a central component to mitigate droughts effects. Aligning the town aesthetics for drought-friendly water practices, updating the public utility for best practices prior and during droughts, promoting cultural events for the farming and ranching community and incorporating best management practices for fire mitigation are key actions for town management. Incorporating seasonal and annual forecasts as well as future climate projections in management practices will also help to support more informed decisions and could serve to create a more drought resilient system.

2. Introduction:

Source: www.carbondale.com

Carbondale is a mountain town in the Roaring Fork Valley on Colorado's Western Slope, with a population of 6,820. The town lies in southeastern Garfield County. Although the town has multiple water sources—Nettle Creek, the Crystal River, and the Roaring Fork River—it has in the past suffered from drought and in 2018 experienced one of the most severe droughts to date. The town has put into place water conservation measures to try and mitigate the impacts of drought. Nevertheless, with a growing population and likely higher drought frequency in the future, the town has a growing interest in climate resiliency and integrating an understanding of projected impacts of climate change into town planning and operations.

On September 26-27, 2018, the town of Carbondale participated in a Vulnerability, Consequences, and Adaptation Planning Scenarios (VCAPS) workshop, which was organized by the Western Water Assessment (WWA) team, an applied research program based at the University of Colorado Boulder. The VCAPS approach uses facilitated discussion to support municipalities in building resilience towards weather and climate hazard and impacts. Prior to the workshop, WWA staff worked with the Town Manager and one of the town Trustees to identify town staff and other community stakeholders to participate in the VCAPS workshop and identify the key management concern to be addressed during the workshop: water supply in the context of drought.

In preparation for the workshop, WWA staff conducted phone interviews with each of the selected participants to collect background information on key concerns, needs and local knowledge associated with climate and weather hazards. As water supply was identified as the key concern, the phone interviews revealed many issues related to water supplies and water use during drought. Wildfire was another drought concern brought up by many. Based on all individual interviews conducted prior to the VCAPS workshop, the WWA team crafted the following objectives for the workshop:

1. Increase **scientific awareness** of **drought and climate impacts,** and come to a shared community **understanding of long-term climate trends**.
2. **Build town staff expertise** about regional climate trends and future climate scenarios to support future **communications about trends** with elected officials and the public.
3. **Take inventory** of current key needs, values, strategies, and opportunities associated with water supply.
4. **Identify options** for adapting town operations to mitigate risks associated with drought, in the light of scientific uncertainty.

During the Workshop, which took place during two half-days, the WWA team gave a science presentation on the current state of knowledge on observed and projected climate change and its impact related to drought in Carbondale and the Roaring Fork Valley. The WWA staff then led the group of stakeholders in a participatory diagraming exercise in which participants mapped out the causal chain of drought events, analyzed existing and anticipated community impacts of drought, identified gaps in knowledge, and brainstormed strategic short- and long-term solutions for mitigating and adapting to increasing drought risks. The remainder of this report will summarize key aspects of the VCAPS process, highlight themes that emerged during the workshop discussions, and synthesize actions identified by workshop participants.

3. Local Climate and Weather Hazard in Carbondale: Concerns and Existing Initiatives (from pre-workshop interviews)

The town has multiple water rights, and its most senior water rights are in the ditch system, diverted from the Crystal River, that runs through Carbondale and that is used mainly as irrigation water in town. The town has senior rights on the south Nettle Springs (1922) but more junior rights on the North Nettle Creek (1971). The Crystal River and Roaring Fork River are important source of potable water in drought conditions.

During the pre-workshop interviews participants expressed interest in advancing demand-side solutions (i.e., water conservation) as key strategies to shore up water supply in the long term. The town staff made it clear they cared about their citizens and were focused on reducing water use as well as maintaining the town's spirit of community.

The town has already made significant efforts to prepare for drought, including workshops on xeriscaping, mandatory water restrictions on outdoor watering for all town residents implemented during drought, reducing water usage for public infrastructure such as parks by 50%, and by having an aggressive Climate Action plan. Nevertheless, participants identified clear challenges associated drought, such as maintaining the town's green spaces, updating and expending their current infrastructure, lacking available water storage, sustaining the ecological health of their rivers, and raising awareness among local residential users about the importance of water conservation.

Especially severe drought conditions emerged during the spring and summer of 2018 and led to rare or even unprecedented impacts. A large and destructive wildfire just up valley from Carbondale led to the evacuation of a portion the nearby town of Basalt, and caused very smoky air on several days. Streamflows in the Crystal River and Roaring Fork River and their tributaries were far lower than normal. For the first time, a water-rights "call" was placed on Nettle Creek, as described later in the report.

When asked what information the participants needed to get the most out of the workshop some expressed the wish to put the current (2018) drought in context. To understand the current drought, it was important for some to have a better understanding of the multi-century paleo-record of drought from tree rings, and others to have an explanation of the role of evapotranspiration in water availability. Some of the interviewees wanted more knowledge on future climate trends regarding drought and wildfires.

4.Local weather and climate impacts: Recent trends and future projections for the Roaring Fork Valley

The water budget and drought

Before describing the observed climate trends and projected future climate for the Roaring Fork Valley, it will be helpful to review the basic water budget (Figure 1). Over the course of the year, Precipitation minus Evapotranspiration (ET) roughly equals Runoff (or streamflow). Evapotranspiration (ET) is the combined loss of water vapor from the soil, water, snowpack, and vegetation—and it has a profound influence on water availability. In a typical water year (October-September), averaged across the Roaring Fork basin above Glenwood Springs, about 30” of precipitation falls, mainly as snow. About 60% of this precipitation will return to the atmosphere (that is, ET) without reaching the Roaring Fork and its tributaries (Figure 1, left). The remaining 40% will run off and be available for use by people, and in the stream and riparian ecosystems.

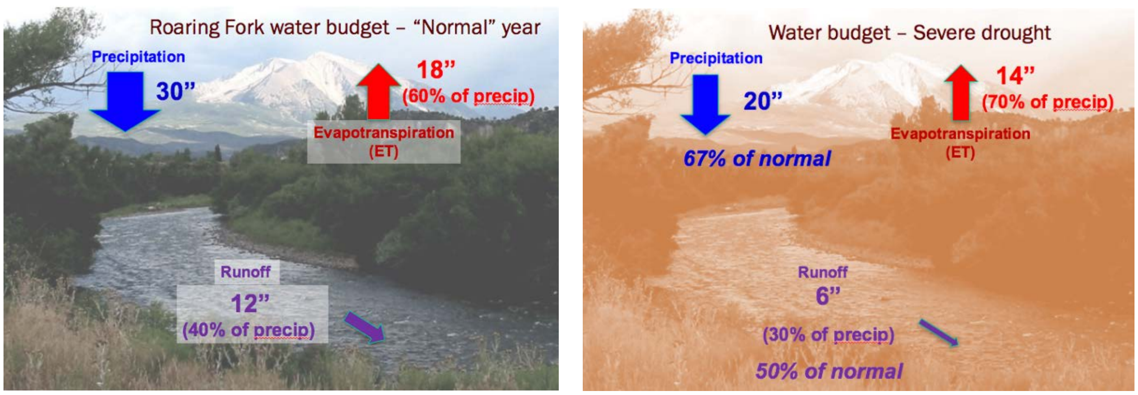

Figure 2: Schematic of the Roaring Fork Basin water budget in a normal-precipitation year (left) and in a severe drought year (right). During severe drought years, such as in 2002 and 2018, the fraction of precipitation that is taken back up by the atmosphere (evapotranspiration; ET) goes up, so runoff is disproportionately reduced compared to precipitation

In severe drought years, like 2012 or 2018, precipitation is about one-third lower than normal, or about 20” across the Roaring Fork basin. Because dry weather patterns are also associated with warmer temperatures, severe drought years are typically much warmer than normal, as well as having more sun and lower humidity. All of these factors tend to increase ET—the atmosphere is “thirstier” during a drought. The fraction of precipitation going to ET increases to around 70%, and thus runoff is disproportionately reduced, to only half ofnormal (Figure 1, right). So the smaller snowpacks, lower streamflows, and parched soils and vegetation associated with severe droughts result from both reduced precipitation *and* greater moisture loss through ET.

Observed Precipitation: High variability, no recent trend

If we look at the record of precipitation as averaged across Pitkin County—to represent the Roaring Fork Valley and the Carbondale area—we see that annual precipitation has had large swings from year to year, and smaller shifts from decade to decade, since 1900. This *natural variability* is mainly caused by fluctuations in the prevailing tracks of storms in fall, winter, and spring that bring moisture from the Pacific Ocean. In the very driest years—1931, 1934, 1977—precipitation was about 18”, or 60% of the long-term average. Even with the most recent severe droughts, there is no clear trend in precipitation; the average precipitation

since 2000 is about the same as the average over the 20th century. For water year 2018 (October-September), precipitation was slightly below normal in Carbondale, but much lower than normal in the higher elevations of the Roaring Fork Valley where the flows of the Roaring Fork River and Crystal River originate.

Observed Temperatures: A strong recent warming trend

The record of annually-averaged temperatures (over the water year, October-September) for Pitkin County shows a very different picture from precipitation. There has been a strong upward trend in temperatures over the past 40 years that stands out from the year-to-year natural variability (Figure 2). The average temperature since 2000 has been 2.2°F higher than the 20th-century average, with 4 of the 5 warmest years coming in the 21st century: 2000, 2012, 2017, and 2018. The 2018 water year that ended on September 30 was in fact the very warmest in over 120 years of record, over 4°F higher than the 20th-century average. By themselves, warmer temperatures have an overall *drying effect*: ET tends to increase as a fraction of precipitation, snowpacks and streamflows tend to decrease, snowmelt and runoff come earlier, and soils become drier in the summer.

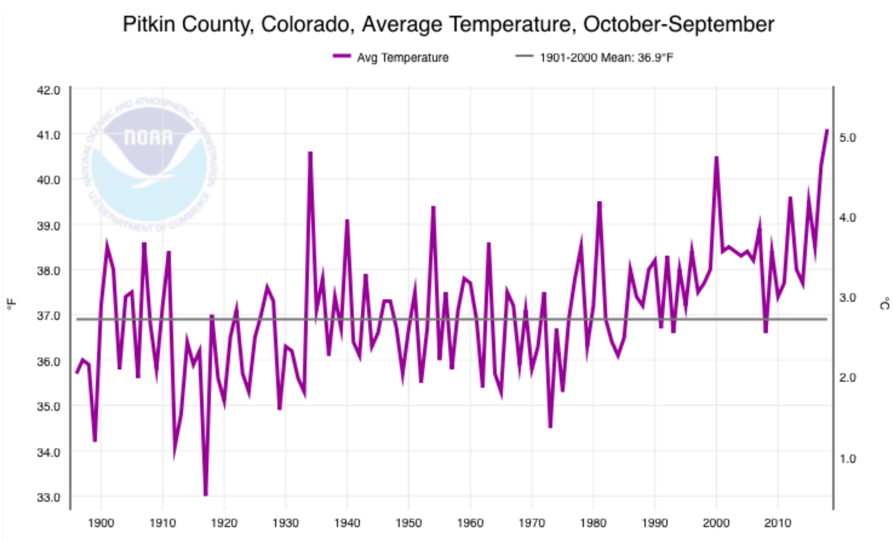

Figure 3: Annual (water-year) average temperature for Pitkin County, 1896-2018. Temperatures since 2000 have been over 2°F warmer than the 20th-century average, and 2018 was the warmest water year on record. (Source: NOAA NCEI; https://www.ncdc.noaa.gov/cag/)

Observed snowpack and streamflow: A little earlier, a little less

The vast majority (70-85%) of the streamflow in the Roaring Fork originates as melting snow; the snowpack acts an enormous seasonal reservoir that accumulates water during the cold season (October-May) and releases it during the spring runoff season, mainly May and June. In the Roaring Fork and other basins in western Colorado, there has been small declining trend in the peak spring snowpack, and the snowmelt is occurring earlier, by 1-2 weeks, since the 1980s.

The record of annual *naturalized* streamflows for the Roaring Fork at Glenwood Springs (adjusted for diversions and depletions) from 1920-2016 shows large year-to-year swings, and smaller decade-to-decade shifts, similar to the record of annual precipitation. Since 2000, Roaring Fork streamflows have been about 13% lower than the 20th-century average, in contrast with the Routt County precipitation record, which shows no decline since 2000. This period has included four drought years with annual (water-year) streamflows that were only 50-60% of the long-term average: 2002, 2012, 2013, and 2018. It is likely that at least some of the recent reduction in streamflows is due to the effect of the warmer temperatures.

To get a longer frame of reference for recent droughts, we can look at Roaring Fork streamflows estimated from the ring-widths of long-lived, moisture-sensitive conifers like Douglas-fir and pinyon pine. This paleo-streamflow record shows many individual years that were worse than the lowest recorded annual flow (1977), and also several multi-year droughts that were worse than those in the post-2000-period. These droughts could potentially recur in the future, under a warmer climate.

How recent trends in the Roaring Fork are connected with expected future changes

The recent warming that has been observed in the Roaring Fork Valley and across Colorado is part of broader warming trends that have documented regionally, nationally, and globally. This unusual and widespread warming has been attributed to increasing levels of greenhouse gases, such as carbon dioxide (CO_2), in the atmosphere; CO_2 is now at its highest level in at least 1 million years, according to ice cores.

How much will the climate change in the future, and in what ways? Global climate models, or GCMs, give us our best view—though still hazy—of the future climate. They are computer-based tools that incorporate the fundamental laws and equations of physics, and our observations and knowledge of the Earth system, to project the climate forward in time given assumptions about future emissions of greenhouse gases. Figure 3 below shows climate projections from 20 different climate models that have been run forward for the 21st century under two such assumptions: A higher-emissions scenario, with no global efforts to restrain emissions, and a lower emissions scenario, which assumes that annual global emissions are reduced by two-thirds after 2040.

Future temperatures: Even warmer, and into uncharted territory

All climate models indicate that the climate of the Roaring Fork Valley will continue to warm well into the 21st century (Figure 3). Under the lower-emissions scenario, by 2050, average temperatures are projected to be 3-5°F warmer than the late-20th century average, and 3-7°F warmer by 2080. Under the higher-emissions scenario, the warming would be even larger, with temperatures 4-6°F warmer by 2050 and 7-11°F warmer by 2080. Warming will move climate zones both uphill and upvalley; a future warming of 6°F would mean that Aspen would then have the current temperature regime of Carbondale. Under either emissions scenario, by 2050, the typical year in the Roaring Fork Valley would be warmer than the hottest years of the 20th century. Returning to the water budget described above, this much warmer future climate would create mild drought conditions even during years of average precipitation, by increasing evapotranspiration.

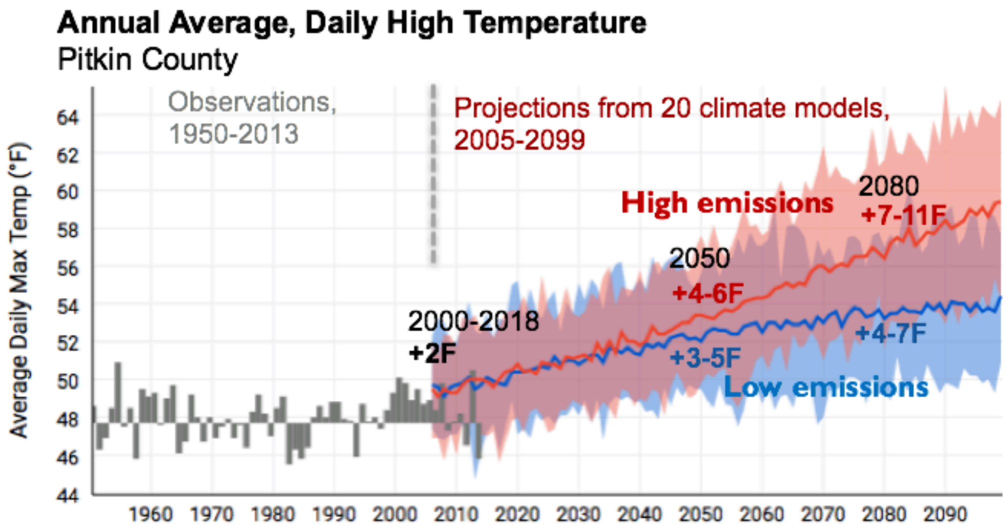

Figure 4: Projected annually-averaged daily high temperatures for Pitkin County, 2005-2099, from 20 climate models under 2 emissions scenarios, compared to observed temperatures, 1950-2013 (Source: NOAA Climate Explorer)

Future precipitation: Unclear changes, but large variability will continue

In contrast with the near-certainty of future warming, it is unclear how annual precipitation will change in western Colorado by 2050, relative to the late 20th century. Some climate models show modest increases in annual precipitation, some models show modest decreases, and some models show it remaining about the same. All models show continuation—if not enhancement—of the large year-to-year variability in annual precipitation.

Future snowpack and streamflow: Earlier melt and runoff, probably less water overall

Future climate projections like those shown in Figure 3 have been used as inputs to basin-scale hydrology models to estimate how future snowpack and and streamflow may change in the future. Most of these hydrology projections show that April 1 Snow-Water Equivalent (SWE) for western Colorado and the Roaring Fork will decline by 2050 by 5-20%, due mainly to the effects of warming. These projections also show the snowpack melting out yet earlier in spring than recent years, by another 1-3 weeks by 2050. As one would expect with warmer temperatures and declining snowpacks the projections also show that annual streamflows in western Colorado are likely to decrease by 2050, by as much as 20 to 30%, though under less likely climate outcomes (less warming plus higher precipitation than today) there could be modest increases in streamflow.

Future drought, wildfires, and flooding: More frequent, more intense

The frequency and intensity of droughts is expected to increase in the future due to the warmer climate, even with the uncertainty in future precipitation trends. Extreme drought

events like 2002 and 2018 will occur more frequently than in the 20th century, and drought conditions, once established, are likely to persist longer. Multiple studies that have modeled future changes in wildfire all indicate that due to the warming, the fire season will become longer, fire severity will increase, and the annual area burned by wildfires across Colorado will increase significantly by mid-century. There is also confidence that the intensity of the heaviest rainfall events will increase with warming temperatures; it is likely that extreme rainfall events will become 10-20% larger overall by 2050. This would increase overall flooding risk and fire debris flows, especially in combination with the increasing area that has recently burned.

Further information

For more information about climate trends, and climate change impacts for Colorado and the Roaring Fork Valley, see these resources:

Lukas, J., and others. 2014. *Climate Change in Colorado: A Synthesis to Support Water Resources Management and Adaptation.* A report for the Colorado Water Conservation Board. Western Water Assessment, University of Colorado Boulder. http://wwa.colorado.edu/climate/co2014report/Climate_Change_CO_Report_2014_FINAL.pdf

Arnott, J., and others. 2014. *Climate Change & Aspen. An Update on Impacts to Guide Resiliency Planning and Stakeholder Engagement.* A report by the Aspen Global Change Institute prepared for the City of Aspen. https://www.cityofaspen.com/Archive/ViewFile/Item/328

Lukas, J. 2017. Warmer—But to What End? The Past, Present, and Future Climates of the Roaring Fork Valley. Presentation for Naturalist Nights, Wilderness Workshop, Carbondale, January 25, 2017. 69 min. https://www.youtube.com/watch?v=514UkvsAACs

5. VCAPS Workshop : Highlights and Themes

a. Description of the Workshop Process

During the workshop on September 26-27, 2018, participants took part in two separate diagramming exercises/discussions beginning with water supply as the key management concern: one exercise examining a severe drought year and one exercise examining a multiyear drought scenario. At the beginning of each exercise, the WWA facilitator solicited from the group a specific drought scenario to discuss. During the discussions, one WWA team member facilitated the group discussion while another team member diagrammed the conversation in real-time (see Figure 4) and projected it onto the screen so that the participants could see the diagram being populated with ideas as they were being generated. The Carbondale group chose the following scenarios to diagram:

- Drought Scenario 1: current (2018) one-year severe drought;
- Drought Scenario 2: a 2018-type drought extended for multiple years;

During each diagramming exercise, the WWA facilitator led the group through the process of mapping out the causal chain of outcome and consequences related to the climate hazard (i.e., drought) – starting with a ***management concern*** (e.g., water supply) and ***climate stressors*** (e.g., increased temperature and decreased precipitation), and then identifying the physical and social ***outcomes*** and ***consequences*** that stem from those climate stressors. The WWA facilitator asked questions such as "Why do we care about [climate stressors]?" to guide the group to identify the potential outcomes for the community that would be problematic for the town. The causal chain of the hazard was considered completed when the outcomes generated by the discussion encompassed direct consequences, i.e., loss or harm to things the community cares about, such as people, assets, and ecosystems.

The VCAPS Diagramming Framework

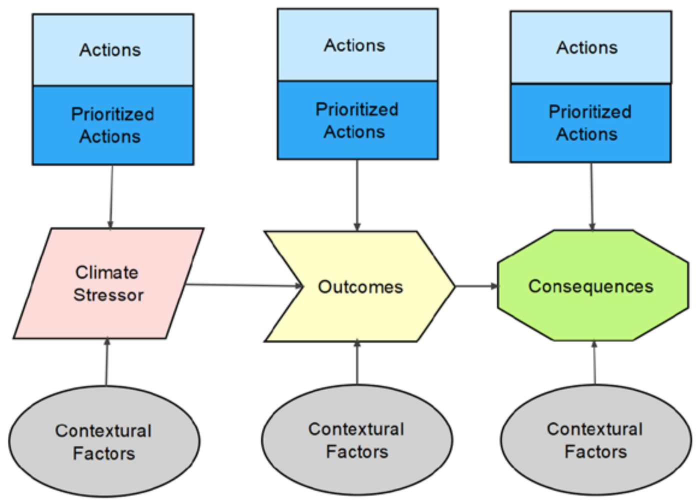

Figure 5: VCAPS building blocks

Throughout the process, WWA staff listened for mention of ***contextual factors****,* or factors unique to Carbondale's specific community or management context that influence the town's ability to cope with a particular outcome or consequence. Once the causal structure was completed, the WWA facilitator then led the group in a discussion of potential ***actions*** that the town could take to address different outcomes and consequences.

The final versions of the two diagrams are included in Appendix B, and the *actions* from each diagram are summarized in Appendix A. The following sections summarize the key discussion points of each diagraming exercise.

b. Discussion Themes: Drought Scenario 1 (2018-Type Drought)

During the discussions for the first diagramming exercise, in which participants mapped out the causal structure of a 2018-type drought, the group started with *warmer temperatures* and *reduced precipitation* as the key climate stressors relevant to water supply management, the management concern selected to frame the overarching discussion. The diagram generated through the group discussion focused on multiple issue areas: (i) Reduced runoff, (ii) Stress on ecosystems, (iii) Fires, (iv) Reduced water supply, (v) More concentrated solids in waste water, (vi) Tourism, (vii) Reduced irrigation for town facilities, (viii) Reduced water for agricultural irrigation out of town, (ix) Call on the Nettle Creek.

i. Reduced Runoff

Reduced runoff, which served as the central theme for all other main outcomes, is caused by the two main climate stressors: warmer temperatures and reduced precipitation. All other issues were directly or indirectly linked to reduced runoff. Participants acknowledged that the risk of low flows in the Crystal was underappreciated prior to the 2018 drought.

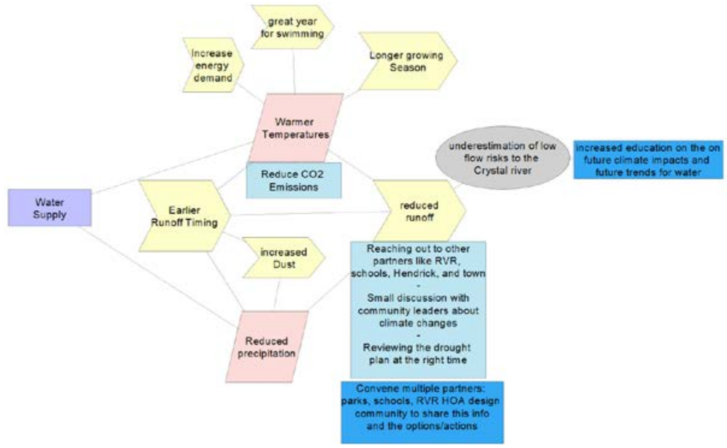

Figure 6: Outcomes, contextual factors and actions linked to reduced runoff. See appendix B for full diagram

The group identified multiple actions focusing on education to help mitigate the consequences of reduced runoff. To ensure that town residents increase their awareness of the water situation in the town and the possibility of drought, the group proposed convening partners such as River Valley Ranch, Schools and Parks as well as community leaders to share the information gathered during this workshop. They also suggested increasing education in general on future climate impacts and future trends for water in the region. Finally, it was suggested that having a follow-up meeting could take advantage of the momentum created by the workshop and build support for actions to be taken by participants as well as others beyond the workshop participants. (See appendix A for full list of actions)

ii. Stress on Ecosystems

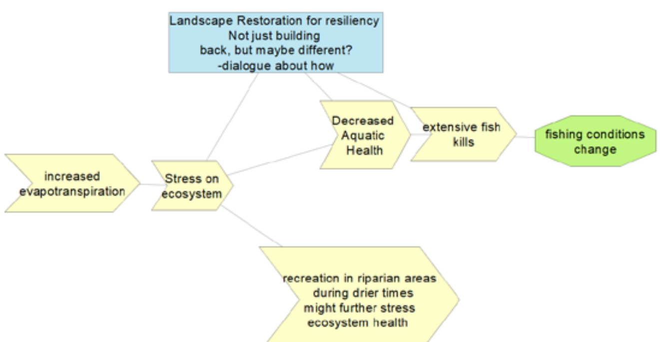

Figure 7: Outcomes, consequences and actions linked to the stress on the ecosystems. See appendix B for full diagram

Stress on ecosystems is an outcome linked to reduced runoff, as well as increased evapotranspiration. The group identified multiple outcomes stemming from increased stress on ecosystems. Decreased aquatic health can lead to extensive fish kills which in turn would have negative effects on the fishing conditions in the region. It was also noted that any recreation in riparian areas during drought periods would further exacerbate the stress already impacting ecosystems.

The group proposed the action of restoring ecosystems to augment their resilience. Because the restoration efforts needed in a severe drought might be extensive, there was a suggestion to convene a dialogue on how to think about landscape restoration in a changing landscape, taking into consideration possible climate influences and how conditions might dictate a different approach rather than only “building back”.

iii. Fires

Increased fire risk was an outcome linked to the stress on ecosystems, namely forests and shrublands. There were two categories of outcomes stemming from increased fire risk. The first one was the potential impact from a fire causing electric outages. The important contextual factors identified here is the lack of experience with power loss in the town and the lack of backup generators for the water treatment plant in case of electrical outages. An electrical outage would have the potential to impact the water treatment which in turn would have effects on public health. Electrical outages could also pose a serious threat to municipal services such as hospitals, schools, emergency centers and other places of refuge.

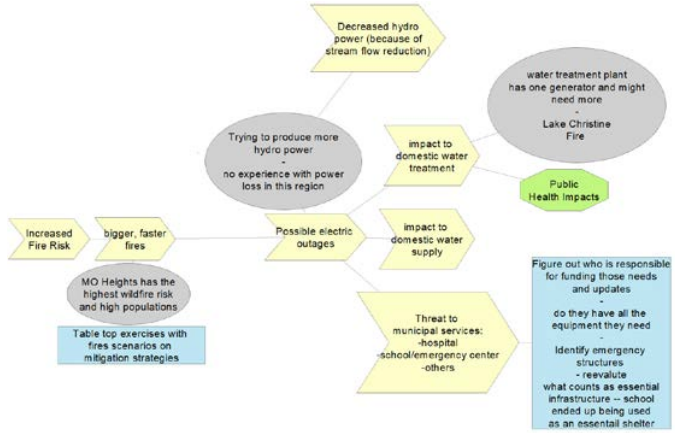

Figure 8: Outcomes, consequences, contextual factors and actions linked to increase in fires frequency. See appendix B for full diagram

The group identified multiple management actions to improve preparation for any impact from fires to their electrical grid. They proposed identifying and possibly reevaluating what counts as "essential infrastructure" (e.g., the school was used as an essential shelter during the Lake Christine Fire), determine if these buildings possess all the needed equipment, and find who is responsible for funding the supplies and updates needed to ensure essential infrastructure is prepared in emergencies. One generator has already been sourced as backup power for the water treatment plant and another generator is scheduled for purchase in 2019. It will take a total of two generators to supply backup power to the Roaring Fork Plant and well field due to the locations of these facilities.

The second main outcome due to increased fire risk was the increase in demand on resources to fight these fires. During the Lake Christine Fire, because of aiding other communities, Carbondale had only a 3-person fire crew left in town to deal with any fire outbreak closer to town. The group proposed to educate the population about how resources can be spread thin during fires and create a ballot initiative for a tax to raise additional funds for local firefighting resources.

Nevertheless, this was not the only problem linked to increased demand on resources for firefighting. In a drought year, fires are larger and harder to fight, and therefore may last longer, which could have multiple effects—some positive, most negative. As was the case in 2018, when fires occur in other parts of the Roaring Fork Valley, Carbondale could become a sanctuary for people evacuating from the fires, which in turn could increase the town's revenue, although perhaps creating pressure on shared public resources. On the other hand, fires could shut down nearby airports (as in 2018), negatively impacting tourism in the region, and

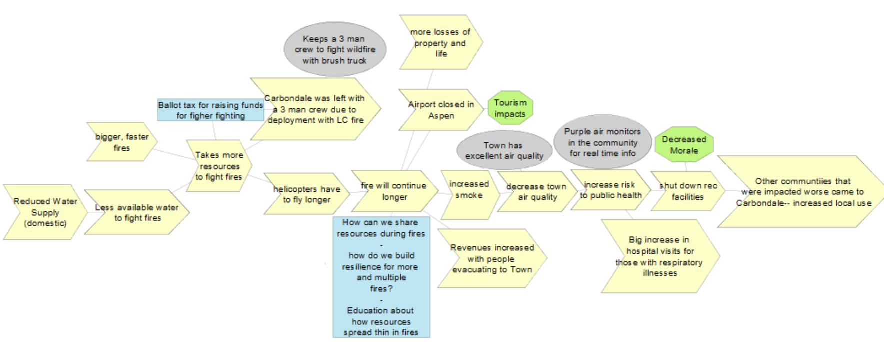

Figure 9: Outcomes, consequences, contextual factors and actions linked to an increase in resources to fight fires. See appendix B for full diagram

cause smoky air in town. Carbondale has the reputation of having excellent air quality and a decrease in air quality would not only lead to public health risks but also have an impact on community morale. No actions were identified regarding this issue due to lack of time.

iv. Reduced Water Supply

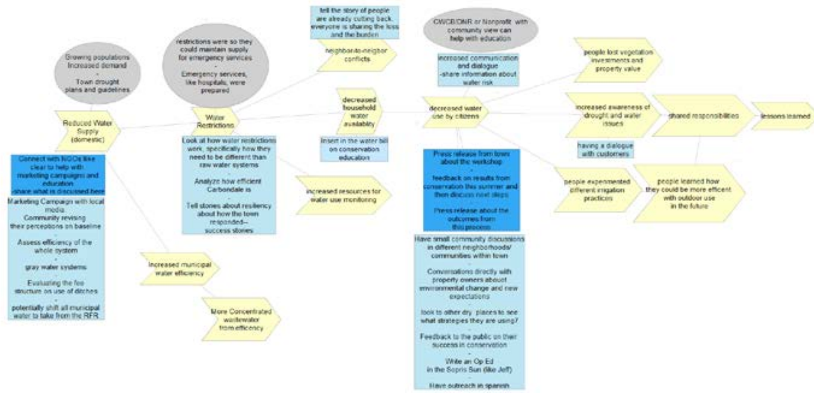

Figure 10: Outcomes, contextual factors and actions linked to a reduction in water supply. See appendix B for full diagram

Reduced water supply in town was an outcome of reduced streamflow and led to many subsequent outcomes. Because of reduced water supply during the 2018 drought, the town had to put in place outdoor watering restrictions. Irrigation restrictions are implemented first, followed by domestic household use restrictions, restaurant restrictions, and so on. These restrictions were needed to maintain the supply for emergency services and decreased overall water use by residents. There was a concern that restricted watering could lead to people losing investments in landscaping and affect property value. Ultimately it was agreed that obligating citizens to reduce their water use might have served as a wake-up call for many, increasing awareness towards drought and water issues, and creating a feeling of shared responsibility in the community. Carbondale also has a growing population which, if that translated into increased municipal water demand, would be an additional stressor during future droughts.

A number of actions were identified to help mitigate the impact from this issue. The problem of reduced water supply could be better understood with an efficiency assessment of the whole system. Reaching out to NGOs like CLEER to help create marketing campaigns and help with education could modify negative public opinions about water restrictions. To further conserve water during drought periods, other proposed actions were creating a gray-water system and evaluating the fee structure on the use of ditches.

The water restrictions implemented in 2018 were successful in helping the town cut back on total water usage, but there was concern that neighbor-to-neighbor conflicts arose from different views on water use and conservation. To increase awareness of the water situation around Carbondale, and the diversity of local perspectives on water, it was proposed to share with the public the story of the citizens successfully reducing their water uses and how that had helped the town avoid more significant water-related impacts. This could help residents see water conservation as a collective effort, would give recognition to the residents who were already participating, and could raise the town morale. Other actions proposed by the group included issuing a press release from the town about the VCAPS workshop, organizing small-community discussion groups in neighborhoods and surrounding agricultural lands, and having outreach in Spanish to include all citizens of Carbondale (see full list of actions in Appendix A).

v. More Concentrated Wastewater Solids

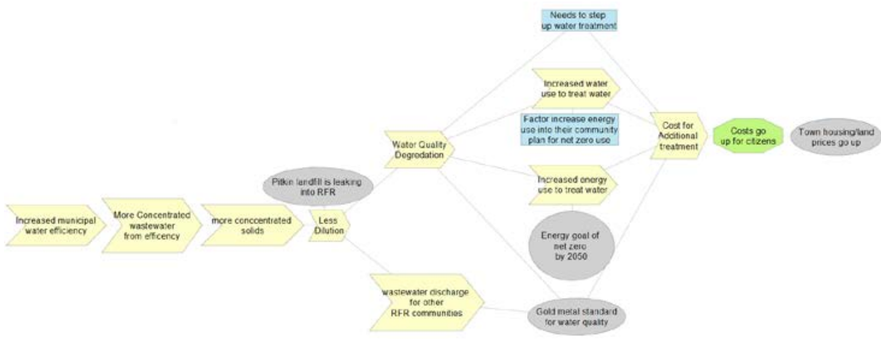

Figure 11: Outcomes, consequences, contextual factors and actions linked more concentrated wastewater solids. See appendix B for full diagram

An unintended consequence of more efficient household water use is the increase in the concentration of solids in wastewater. This could lead increased costs and energy use for treating wastewater in Carbondale. An important contextual factor linked to this issue is that Carbondale treats not only its own wastewater but other communities wastewater as well. Any increase in energy use to treat wastewater would run counter to Carbondale's goal of being a zero-net-carbon-emissions town by 2050.

More concentrated solids in the wastewater system will increase the demand of energy for water treatment and will require increased operations of mechanical equipment. This signifies additional costs for town in treating their water and ultimately additional costs for the citizens of Carbondale.

The main action listed here by the group is the need to increase the capacity of the wastewater treatment plant to be better adapted for future needs. The staff made a point of needing to account for any increase in energy use for wastewater treatment as part of their community goal of zero net emissions by 2050. Staff is seeking alternative energy opportunities wherever possible.

vi. Tourism

Since Carbondale's economy strongly depends on its tourism and related recreation, it is critical for the town to preserve the values that draw tourists to the area. One important outcome linked to reduced runoff is the decrease in river recreation and access to fishing because of reduced flows. Drought also impacts local forest and riparian areas, which may become degraded in drought and result in closures to recreation access.

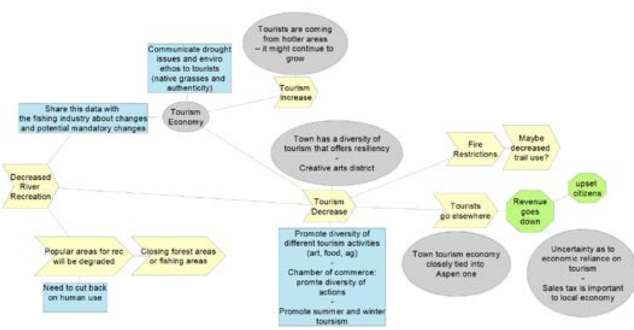

Figure 12: Outcomes, consequences, contextual factors and actions linked to a decrease in tourism. See appendix B for full diagram

Overall reduction in river recreation can lead to a decrease in tourism, which would cause the town's revenue to be reduced, and also affect residents whose employment depends on tourism. It was pointed out that Carbondale has diverse attractions and opportunities for tourism, which offers some resilience to a reduction in river recreation. An important point was made that tourism might even increase over the coming decades as most of the tourists reside in warmer areas of the country. As the climate becomes yet warmer,

Carbondale might become even more attractive as a relatively cool mountain retreat, increasing tourism revenues.

Multiple actions were suggested by the group to help deal with this issue. First of all, it was recognized that there would continue to be a need in drought to cut back on recreation use in some sensitive areas to avoid degrading them further. Advertising the town effort in water conservation to tourists might help them better understand any change in recreational use and aesthetic values during droughts. Finally, promoting diversity in tourism activities during summer as well as winter could help alleviate potential decreases in tourism due to drought.

vii. Reduced Irrigation for Town Facilities

This outcome stems once more from reduced runoff in the streams and rivers which feed the irrigation ditches that run through town. A reduction in irrigation poses two major challenges. The overall town aesthetics—of which the ditches are a major part--might change, and parks and other recreational facilities would have to adapt to a decrease in water availability for irrigation.

Traditional water-thirsty vegetation becomes harder to grow in drought and overall town landscaping may need to be modified to a new water regime, e.g., through installing xeriscaping. This, in turn, may not only impact tourism but the residents' morale as well, if they expect more traditional grass lawns, fields, and other lush vegetation. An important contextual factor linked to this last point is that there is a lack of common community vision about what the town aesthetics *should* be as the community responds to climate change.

During drought, recreation facilities (i.e., sports fields) can face a decrease in turf health if watering is reduced. This can have two effects. One way to counteract reduced water is to raise the mowing height (i.e., longer grass), which impacts the playing quality of the sports fields in town. Secondly, reduction in irrigation for parks and recreation can create harder surfaces and reduce the safety of those areas. This could lead to an overall lower participation in recreational programs. This would lead to complaints from the public, which might decrease the town staff morale. It was also mentioned that different turf care practices

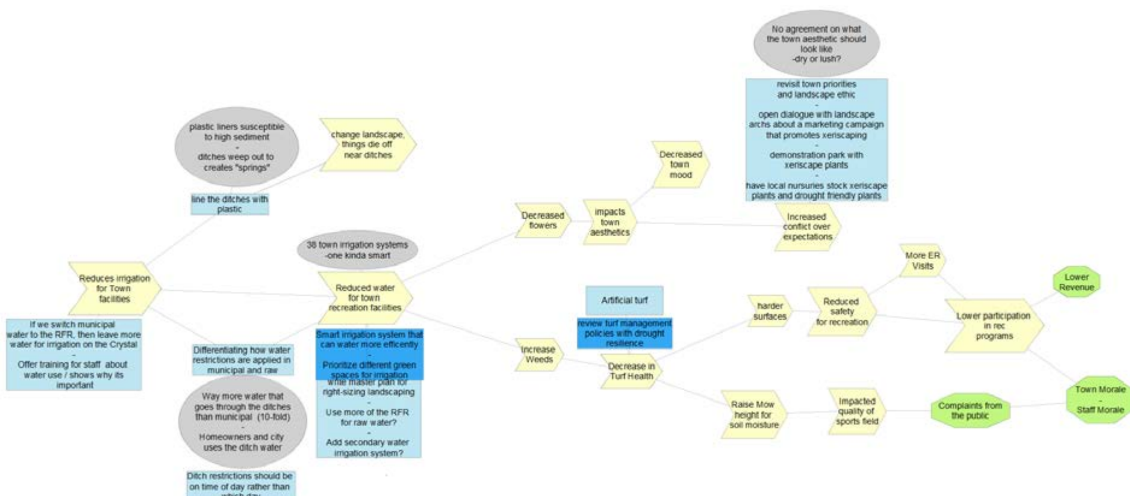

Figure 13: Outcomes, consequences, contextual factors and actions linked to reduce irrigation for town facilities. See appendix B for full diagram

could maintain the quality of turf and require less water, but these would need to be more widely implemented than at present.

Several actions were identified by the group to mitigate these issues. It was proposed to line the ditches with plastic liners to conserve more water. This action requires careful consideration because it would reduce the ditch leakage which indirectly provides water to the vegetation around the ditches, potentially jeopardizing that landscape, and the liners make it difficult to clear sediment deposits from the ditches. For individuals who use the ditches for landscape watering, thought could be given to how to implement restrictions on irrigation so that they work best with the natural flows of the ditches (e.g., a time of day rather than certain days of the week).

Town recreational facilities and aesthetics could benefit from other proposed actions, including prioritizing the watering of different community green spaces, deployment of a 'smart' irrigation system to use water more efficiently, right-sizing the town landscaping, increasing the use of artificial turf, and reviewing turf management policies in light of drought resilience.

Conflicts over expectations surrounding town aesthetics could be reduced by having open dialogues with residents and professionals with different expertise, such as landscape architects. If the town decided to rethink the landscaping needs of Carbondale, as with several of the proposed actions above, an outreach campaign may be needed to get the word out. In addition, using parks as a demonstration for xeriscape plants and creating connections with local nurseries to stock xeriscape- and drought-friendly plants would help improve the ability of residents to take individual action on their own properties, reducing overall outdoor water use in town.

viii. Reduced Agricultural Irrigation out of Town

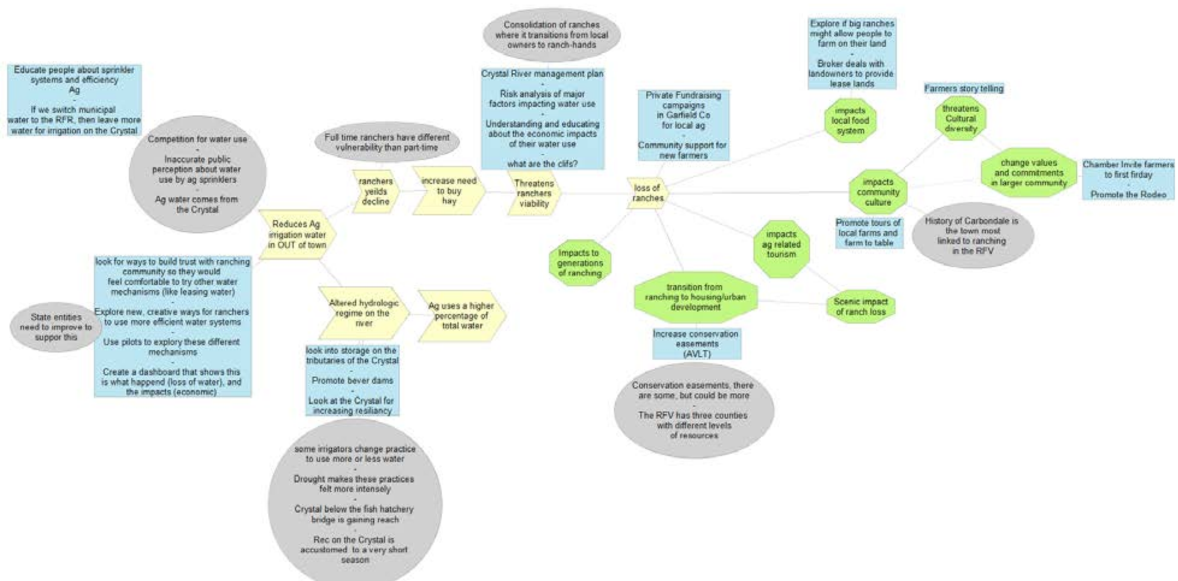

Figure 14: Outcomes, consequences, contextual factors and actions linked to reduced agricultural irrigation out of town. See appendix B for full diagram

It was also clear from this past year that in drought, reduced water availability for agricultural irrigation also was an important outcome of reduced runoff. There are many contextual factors that surround this main outcome. The agriculture community depends, in many cases, on the same sources of water as the town. There also seem to be misconceptions

and related mistrust about the use of water by the agricultural community, specifically, the water used by the more-visible sprinkler irrigation relative to flood irrigation. While flood irrigation may produce greater return flows compared with sprinkler irrigation, the sprinkler irrigation produces more yield per amount of water consumed, so is technically more efficient from that perspective.

The actions that were discussed focus on educating the public and trust building between the agriculture community and other residents. The lack of understanding of ranching lands' dependence on water for their livelihood could be addressed through community dialogue and perhaps some sort of dashboard or shared information site to demonstrate how the use of water by different industries or residential use results in community benefit. Information regarding efficient irrigation practices could also be shared among ranchers.

Drought creates a real hardship for many ranchers in the Carbondale area. The reduction of irrigation water for ranchers can cause reduced hayfield yields. When this leads ranchers to buy supplemental hay, the additional cost threatens their viability. If drought persists too long, ranchers may be forced to sell to non-ranchers, and the area may lose some of its historic ranching lands. This has not only the potential to create consequences such as impact on the local food system, community culture and values, and cultural diversity but also on tourism centered on the agriculture community. In general, it would hasten the ongoing land-use changes from ranching to urban development in the Roaring Fork Valley.

A number of actions were identified by the group to improve the viability of ranching during drought and avoid the loss of ranches. Participants suggested creating private fundraising campaigns in Garfield County for local agriculture, promoting tours of local farms as well as using the rodeo to promote the presence and value of ranchers to the community. Other suggestions included developing tourism linked to agriculture, educating the public via farmers' storytelling, and educating the non-agricultural community by helping them better comprehend the economic impact that water use by agriculture has. Finally, it was also proposed to update the management plan in a cooperative manner for the Crystal River that could identify additional vulnerabilities, produce a risk analysis of Crystal River water availability, and explore possible water storage on the Crystal River.

The reduction of diversions and return flows from agricultural irrigation can lead to changes in hydrology on some reaches of the river. Some irrigators change their practices to use more water during dry periods, to augment the diminished rainfall. These practices, while considered essential by the irrigators, tend to exacerbate the runoff reductions during drought. This leads to very short seasons for recreation on the Crystal River.

Possible actions the group suggested were to find storage on the tributaries of the Crystal River. Promoting beaver dams was also suggested.

ix. Call on Nettle Creek

Finally, the last major drought outcome linked to reduced agricultural water was the "call" placed in 2018 on Nettle Creek—the first time this had ever happened. This occurred because the senior water-rights holders found insufficient water in the stream to satisfy their legal diversion rights, so they called on more junior users to reduce their diversions. This call almost resulted in 42 homes losing access to their domestic water. To maintain the water flowing to these 42 homes, the town had to borrow water from more senior water users in the surrounding agricultural lands. The town was able to keep the water going in these homes

because of this donation, but the situation changed officials' perspectives on where the town's water would have to come from in the future. This led town officials to investigate potential new sources of water, and initiate changes in funding priorities towards physical improvement and expansion of other parts of the town's water system, to ensure options for access to other water in the future.

As this problem had required urgent resolution this past summer, many actions were identified prior to this workshop. Other actions were proposed during the workshop. Together, the actions include adding an upstream pump to bring water to the 42 homes on Nettle Creek, in preparation for any future call. Increasing the capacity of the Roaring Fork water treatment plant is a longer-term action which ties in with the town's plan to add new wells along the Roaring Fork River to access already-owned water stored upstream in Ruedi Reservoir. It was also proposed to increase individual residential water storage (cisterns), and to increase water storage on the Crystal River. It was not known how these options might work given Colorado water law and investigating those options would require some time.

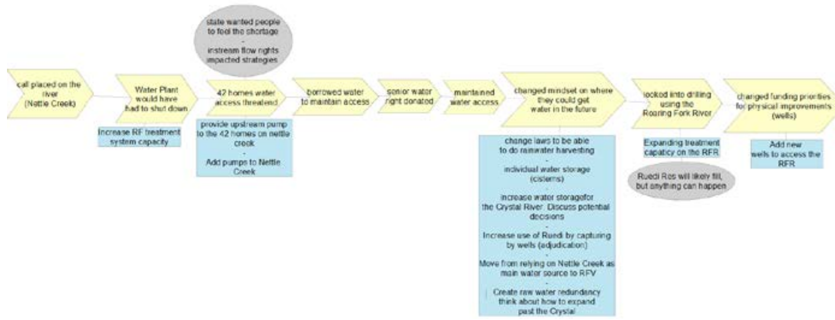

Figure 15: Outcomes, contextual factors and actions linked to a call on the Nettle Creek. See appendix B for full diagram

c. Discussion Themes: Drought Scenario 2 (Multi-year Drought):

The second scenario exercise/discussion was centered around the impacts and needs to deal with even more acute water supply limitations resulting from a multi-year severe drought. Because of limited time, it was not possible for the group to go as in depth into the multi-year drought scenario as the one-year drought event. The main themes that emerged in this shorter discussion were: (i) Stress on Ecosystems, (ii) Increased Fire Risk, (iii) Tourism.

i. Stress on Ecosystems

Ecosystem stress was identified by the group as being one of the major outcomes from a multi-year drought. It is linked to a decrease in water runoff and increase in evapotranspiration. Two major outcome threads that stem from this are aquatic health and increased fire risk.

More stress on ecosystems could lead to an overall decrease in aquatic health in the Crystal River. Higher temperatures could favor invasive species over endemic ones and would lead

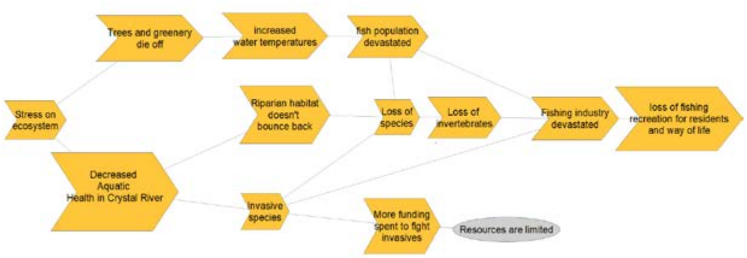

Figure 16: Outcomes and contextual factors linked to an increasing stress on ecosystems. See appendix C for full diagram

to costs associated with removing invasive species.

At the same time extended drought might kill off riparian trees and greenery which would increase water temperatures even more. This could lead to a local ecosystem collapse with fish, invertebrates and other species dying off. This would have a strong impact on local fishing; the loss of fishing recreation would also be a loss of a cherished way of life in the Roaring Fork Valley.

As the main action, the group proposed to identify and assess thresholds for ecosystem change and target efforts ahead of time so as to avoid catastrophic ecosystem loss.

ii. Increased Fire Risk

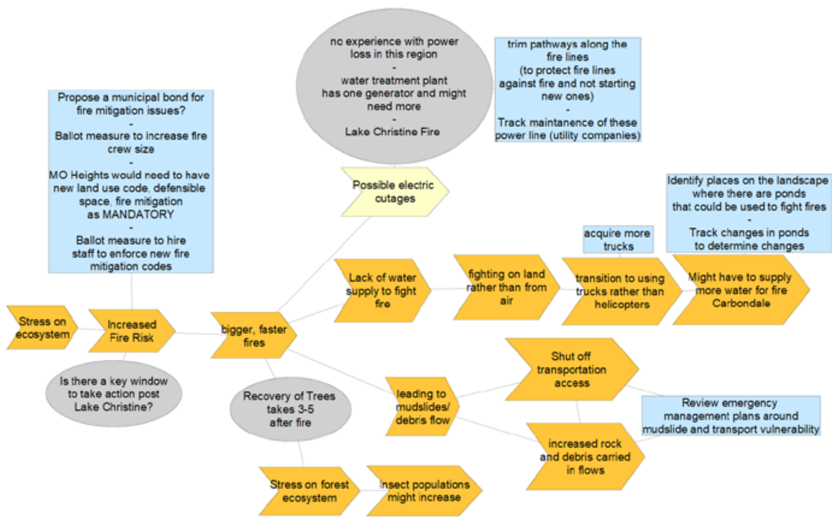

Figure 17: Outcomes, contextual factors and actions linked to an increase in fire risks. See appendix C for full diagram

As in the one-year drought scenario, wildfires were a main theme in this scenario. The greater drought stress on ecosystems could lead to more frequent, larger and more intense fires, which would lead to multiple outcomes.

First, trees that are damaged but not killed by fire have a recovery time of 3-5 years after fires, during which time there could be increases in destructive insects such as bark beetles. Secondly, having more fires might cause debris flows on the affected hillslopes following rainstorms. This could impact the road transportation network in the valley and could cut off access to certain areas. To prepare for this eventuality it was suggested to review emergency management plans around debris flows and transport vulnerability. Thirdly, electrical outages emerged again, this time as a consequence of power poles, power lines, and other infrastructure being directly impacted by fire. Downed power lines touching vegetation are also a cause of wildfire ignition. To help mitigate these risks, the group proposed to create wider clearings along the power lines and to better track the maintenance of the power lines. Finally, a potential reduction of water supply to fight fire (e.g., the drying of local ponds used for aerial bucket drops) would be exacerbated under a multi-year drought scenario. This might constrain firefighters to manage fire only from land-based resources (e.g., fire engines) rather than the air (helicopters). More water supplies might have to be reserved for firefighting rather than used for other water uses in the town. To prepare for such events, the recommended actions were to acquire more fire engines for future needs and identify areas with small ponds that could be used to access water to fight fires.

iii. Tourism

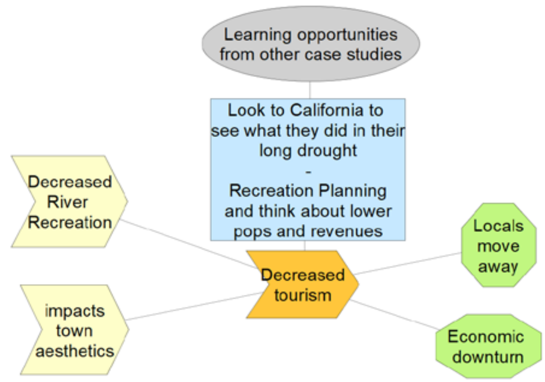

Figure 18: Outcomes, consequences, contextual factors and actions linked to decreased tourism. See appendix C for full diagram

Participants suggested that a significant decrease in tourism could follow from the severe runoff reduction and a decrease in river recreation associated with multi-year drought. This would have serious negative impacts to the town's economy, and could eventually cause local residents to move away from Carbondale. The group identified the need to learn from communities that have faced similar challenges. California was proposed as a source of case studies to understand how communities there dealt with long-term droughts. It was also proposed to do recreation planning that would include scenarios of decreased tourism and revenues.

d. Cross-Cutting themes: (To be completed with the help of the Carbondale group)

During the workshop, several themes repeatedly emerged during discussion of outcomes and actions.

- *Education*: Educating the public came up multiple times in actions proposed by the group to mitigate different impacts of drought. The belief was that giving the public more information related to key consequences of drought, would help mitigate conflicts between residents with different interests, and gain more acceptance for public actions, such as town water restrictions. It was apparent during the workshop that education was seen to be a central piece of many drought-resilience efforts.

- *Facilitating dialogues*: Similarly, facilitating communication and dialogues between residents was seen by the group as applicable to multiple issues. Storytelling about the town's effort in periods of drought like 2018 and the success of residents in saving water was believed to help encourage further conservation efforts while improving sense of community. Facilitating discussions among the town's residents could help reconcile the different expectations that the residents have towards local amenities and services.

- *NGOs*: NGOs such as CLEER, the Aspen Valley Land Trust, and others were often cited as being important actors in the town and valley and a valuable resource during droughts. They are have catalyzed the efforts to create the ambitious local climate action plans. NGOs such as CLEER could help facilitate dialogues with the population, create marketing campaigns related to water restrictions and help better educate citizens about drought and its effects. Overall the NGOs present in town can be pivotal partners when facing drought, potentially helping to bridge the gap between decision makers, citizen, local business and the farming and ranching community. It is important to consider the NGOs as valuable actors for the increase of resiliency in Carbondale.

- *Disparities among residents in opinions and wealth*: There are strong division in opinions about water management in town. Different sectors and residents need water for various reasons (e.g., ranching, guided fishing) and competition for water use may occur between different actors. Wealth inequality is also a major contextual factor for the town. Very wealthy residents and working-class residents are part of the same community, but do not face the same challenges and do not have the same influence over water use and public water issues. It was seen as important to deal with drought in ways that would not exacerbate the pressures on more economically vulnerable residents.

- *Valuing the mountain town aesthetic*: The town of Carbondale is a mountain town with a very authentic feeling to it. The attractive municipal parks and the multiple green spaces give a very lush sensation to the town. These green spaces and key aspects of Carbondale become threatened in times of drought and as droughts are projected to become more frequent in the future, it appears important for Carbondale to refine or redefine its aesthetic. Multiple ideas were proposed during the workshop, including using more drought-resistant plants, creating nurseries for xeriscaping plants and reviewing the right sizing of landscaping. Central to all of these actions is the understanding that in the future, there would be a need to reduce the amount of irrigation water in town.

- *Farming and ranching heritage*: Surrounding Carbondale is a strong farming and ranching community which helps shape the town's identity. This community is a critical part of the town's story, authenticity and atmosphere. Nevertheless, this community is very exposed to the changes in water regimes and thus, during severe drought periods, can be particularly vulnerable. It is crucial for Carbondale to work closely with the farming and ranching community and assist business and NGOs that support and sustain this community during drought periods. Participants also suggested workshops between town residents and the surrounding agricultural community to build shared understanding around water. The workshop group expressed how essential it was to help that community be more resilient to maintain this important part of Carbondale's heritage.

- *Town management:* Town management was a core theme thru the entire workshop. Participants often referred to changing town management practices as a central component to mitigate droughts effects. Aligning the town aesthetics for drought-friendly water practices, updating public utility for best practices prior and during droughts, promoting cultural events for the farming and ranching community and implementing best management practices for fire mitigation are all roles for town management. Incorporating seasonal and annual forecasts as well as future climate projections in management practices will also help to support more informed decisions and could serve to create a more drought resilient system. Overall it is the town management practices that are going to determine a significant part of the exposure, vulnerability and resilience to droughts in Carbondale.

6. Participant Reflections and Next Steps

During the final session of the workshop, participants shared reflections on the two-day VCAPS process. Participants had the following comments on the value of different elements of aspects of the process:

- This discussion has [added value] and will continue to add value in our community discussions and planning efforts related to drought.
- The diagram is a great list [of actions].
- This is a method to take a complex matrix and distill it down to actionable items. I like the process, it really worked.
- Putting all the science, actions and events together made me think how important it is to look at things holistically; reality of how climate change is affecting day to day life.

Participants also shared a number of general next steps they would like to see themselves take, as individuals or as a group:

- Reduce outdoor watering demands by using appropriate landscaping. Make improvements to domestic water supply system following the water master plan.
- Continue open dialogue with all stakeholders.
- Convening stakeholders to discuss how drought impacts our community and next steps. Consider how to manage our water.
- Continue with best management practices in our parks. Share these and their effort with the community.
- Look at [town] budget (and make sure to incorporate meeting action items into budget.

7. Conclusion

The VCAPS methodology is one of many approaches available to empower local adaptation to weather and climate hazards like drought through structured, deliberate dialogue. Over the course of two half-day meetings, the town of Carbondale convened key staff and decision-makers from across the community to systematically examine and document local climate concerns; the experienced and anticipated impacts of climate hazards; knowledge of past, current, and planned efforts to mitigate climate risks; and potential new solutions to address risks across town operations. Nearly all workshop participants expressed the need to continue these discussions. We hope that this report and the diagrams generated from the meetings can support this group to continue the conversation and generate a plan for examining the broad range of vulnerabilities, questions, existing assets, and new ideas that emerged through this process.

Appendix A: Table of Actions Identified During the Workshop

Scenario	Issue Area	Action Status	Possible Actions Identified at the Workshop*[1]	Consequence / Trade-Offs Opportunity
Drought Scenario 1 (2018-Type Drought)	Reduced runoff		Reaching out to other partners like RVR, schools, Hendrick and town	
			Small discussion with community leaders about climate change	
			Reviewing the drought plan at the right time	
			Maintaining proactive steps with the NRCS, Watershed groups and agricultural community early in the year as the winter season recedes	This assists in preparation for the dry summer season
			Reduce CO2 emissions	
			Convene multiple partners: park, schools, RVR, HOA design community to share this info and the options and actions	
	Stress on Ecosystem		Landscape restoration for resiliency. Not just building it back but maybe do it in a different manner. Have a dialogue about how such a process should happen	
	Fires		Table top (simulation) exercises with fires scenarios on mitigation strategies	
			Do municipal services have all the equipment they need in case of emergency	
			Work with property owners on ladder fuel mitigation and defensive spaces and with USFS on forest lands	
			Work with landscape professionals on materials to educate the public on vegetation management during drought conditions (trimming, watering vegetation that is most susceptible to drought, e.g. trees and shrubs)	
			Identify emergency structures and reevaluate what counts as essential infrastructure (schools ended up being used as an essential shelter)	
			Figure out who is responsible for funding those needs and updates	

*[1]Action is defined here as conceptual ideas that emerged at the workshop and are not necessarily possible or commitments.
*[2]All the cells in dark blue color were identified as priority actions by the workshop group.

Scenario	Issue Area	Action Status	Possible Actions Identified at the Workshop*[1]	Consequence / Trade-Offs Opportunity
			Find how can we better share resources during fires	
			Conversation on how do we build resilience for more frequent and intense fires	
			Educate the public about how resources are spread thin during fires	
			Create a ballot tax for raising funds for fire fighting	
	Reduced Water Supply		Connect with NGOs like CLEER to help with marketing campaign and education*[2]	
			Share what was discussed during the VCAPS workshop*[2]	
			Marketing campaign with local media to help community revise their perceptions on baseline	
			Assess the efficiency of the whole water system	
			Evaluate creating a grey water system	
			Evaluating the fee structure for use of ditches	
			Potentially shift most municipal water to take from the RFR	
			Look at how water restrictions work, specifically how they need to be different than raw water systems	Water restrictions in town are important to help maintain supply for emergency services but can also affect the town morale.
			Analyze how efficient Carbondale is	
			Tell stories about drought resiliency and how the town responded to the 2018 drought. Tell success stories of people cutting back on their water use	
			Include an insert on conservation in the water bill to educate the public	
			Increase communication and dialogue with citizen about water risk via nonprofits or CWCB	
			Create a press release from the town about the workshop*[2]	
			Future press release about outcomes from this process*[2]	
			Give feedback on results from this summer's conservations efforts and then discuss next steps*[2]	

*[1]Action is defined here as conceptual ideas that emerged at the workshop and are not necessarily possible or commitments.
*[2]All the cells in dark blue color were identified as priority actions by the workshop group.

Scenario	Issue Area	Action Status	Possible Actions Identified at the Workshop*[1]	Consequence / Trade-Offs Opportunity
			Have small community discussions in different neighborhoods / communities within town	
			Conversation directly with property owners about environmental change and new expectations	
			Look to other dry places to see what strategies they are using	
			Write an Op Ed in the Sopris Sun (like the science presentations)	
			Have outreach in Spanish	
	More concentrated waste water solids		Needs to step up water treatment	Having more solids in the waste water system means that there will be a higher energy use to treat the waste water.
			Factor increase energy use into community plan to be a net zero emission community by 2050	
	Decrease in tourism		Need to cut back on human use in some popular rec areas to avoid degradations.	Carbondale's economy is strongly dependent on its tourism industry. As such it is important to take this aspect of the town in consideration when regulating rec areas and changing town aesthetic
			Share the data from presentation with the fishing industry on changes in the ecosystem and potential inevitable changes in the fishing industry	
			Communicate drought issues and environmental ethos to tourists (to promote native grasses and authenticity)	
			Promote diversity of tourism activities (art, food, ag)	
			Chamber of commerce can promote diversity of activities	
			Promote summer and winter tourism	
	Reduced Irrigation for Town Facilities		Switch municipal water to the RFR, that would leave more water for irrigation in the Crystal	
			Offer training to staff about water use / shows why it's important	

*[1]Action is defined here as conceptual ideas that emerged at the workshop and are not necessarily possible or commitments.
*[2]All the cells in dark blue color were identified as priority actions by the workshop group.

Scenario	Issue Area	Action Status	Possible Actions Identified at the Workshop*[1]	Consequence / Trade-Offs Opportunity
			Line the ditches with plastic where feasible	This could cause higher sediment deposit and could change the landscape around the ditches
			Differentiate how water restrictions are applied to municipal and raw water	
			Could evaluate changing ditch restrictions from time of day rather than a specific day	
			Install a smart irrigation system that can water more efficiently*[2]	
			Prioritize different green spaces for irrigation*[2]	
			Write master plan for right-sizing landscaping	
			Add secondary water irrigation system	
			Marketing Campaign with local media to help community revise their perceptions on baseline	
			Use artificial turf	
			Review turf management policies with drought resilience*[2]	
			Revise town priorities and landscape ethic	
			Open dialogue with landscape architects about marketing campaign that promotes xeriscaping	There is not any clear agreement on what the town aesthetic should look like: Dry or Lush?
			Demonstration park with xeriscape plants	
			Have local nurseries stock xeriscape plants and drought friendly plants	
	Reduced agriculture irrigation out of town		Educate people about sprinkler systems and their efficiency	
			Switch municipal water to the RFR, that would leave more water for irrigation in the Crystal	

*[1]Action is defined here as conceptual ideas that emerged at the workshop and are not necessarily possible or commitments.
*[2]All the cells in dark blue color were identified as priority actions by the workshop group.

Scenario	Issue Area	Action Status	Possible Actions Identified at the Workshop*[1]	Consequence / Trade-Offs Opportunity
			Look for ways to build trust with ranching community so they would feel comfortable to try other water mechanisms (e.g. leasing water)	The State entities need to help support this
			Explore new and creative ways for ranchers to use more efficient water systems. Use pilots to explore these different mechanisms	
			Create a dashboard that shows what can happen (loss of water) and the impacts (economic)	
			Look into storage on the tributaries of the Crystal	
			Promote beaver dams	
			Find ways to increase resiliency on the Crystal River	
			Reference the Crystal River management plan as necessary	
			Risk analysis of major factors impacting water use	
			Help town residents understand the economic need for water use by the agricultural community	
			Identify potential ecological cliffs that may occur on the Crystal River	
			Consider private non-profit campaigns in Garfield County to raise awareness about benefit of agriculture	
			Increase community support for new farmers	
			Explore possibilities in which big ranches might allow people to farm on their land	
			Broker deals with landowners to provide lease lands	
			Increase conservation easements (AVLT)	
			Promote tours of local farms and farm-to-table	
			Storytelling to promote farmers and ranchers	
			Chamber could invite farmers to first Friday	
			Promote the local Rodeo	

*[1]Action is defined here as conceptual ideas that emerged at the workshop and are not necessarily possible or commitments.
*[2]All the cells in dark blue color were identified as priority actions by the workshop group.

Scenario	Issue Area	Action Status	Possible Actions Identified at the Workshop*[1]	Consequence / Trade-Offs Opportunity
	Call on the Nettle Creek		Increase Roaring Fork water treatment system capacity	
			Provide upstream pumps to the 42 homes on the nettle creek	
			Focus on better redundancy for water supply with the Roaring Fork plant capacity	
			Change laws to be able to do rainwater harvesting (state issue)	
			Increase individual water storage (cisterns)	
			Increase water storage on the Crystal River and discuss possible decisions	
			Increase use of the Ruedi Reservoir by adding containment ponds to recharge wells (need adjudication)	
			Consider moving away from Nettle Creek as primary water source for municipal water to the Roaring Fork River instead	
			Create raw water redundancy and think about how to expand past the Crystal River	
			Add new wells to access the Roaring Fork River	
Drought Scenario 2 (Multi-year Drought)	Increase in Fire risks		Propose a municipal bond for fire mitigation issues in conjunction with Fire District	
			Ballot measure to increase the size of fire crews as determined by fire district	
			Missouri Heights would need to have new land use codes, defensible space, MANDATORY fire mitigations, per the County and Fire District	
			Ballot measure to hire staff to help enforce new fire mitigation codes as determined by Fire District	
			Trim pathways along the fire lines (to help protect fire lines against fire and not starting new ones) in conjunction with Fire District	
			Track maintenance of these power line (by utility companies)	
			Acquire more fire trucks as determined necessary by the Fire District	

*[1]Action is defined here as conceptual ideas that emerged at the workshop and are not necessarily possible or commitments.
*[2]All the cells in dark blue color were identified as priority actions by the workshop group.

Scenario	Issue Area	Action Status	Possible Actions Identified at the Workshop*[1]	Consequence / Trade-Offs Opportunity
			Identify places on the landscape where there are ponds that could be used to fight fires as determined by the Fire District and County	
			Track ponds to monitor if available water is sufficient to fight fires as determined by the fire district and county	
			Review emergency management plans around mudslide impacts to vulnerable transport systems as determined by the Fire District, County, and CDOT.	
	Decrease in tourism		Look to California case studies to see what they did in their long droughts	There are learning opportunities from other case studies
			Think through how to plan for possible economic downturn during extended drought	

*[1]Action is defined here as conceptual ideas that emerged at the workshop and are not necessarily possible or commitments.
*[2]All the cells in dark blue color were identified as priority actions by the workshop group.

Appendix B: Diagram of drought scenario 1

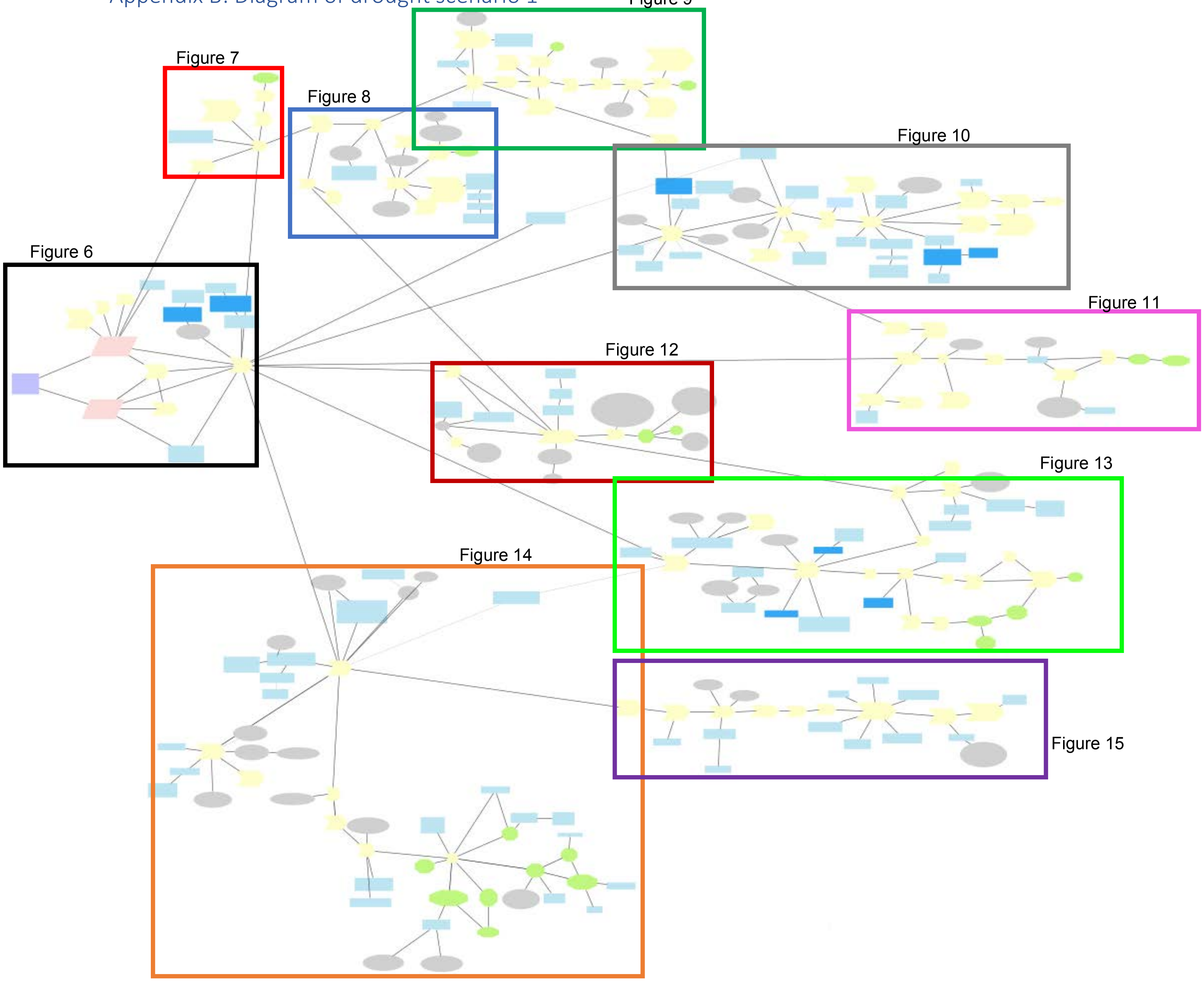

Figure 6: Reduced Runoff
Figure 7: Stress on Ecosystems
Figure 8: Increased Fires Frequency
Figure 9: Increase in Resources to Fight Fires
Figure 10: Reduced Water Supply
Figure 11: More Concentrated Wastewater Solids
Figure 12: Tourism
Figure 13: Reduced Irrigation for Town Facilities
Figure 14: Reduced Agriculture Irrigation out of Town
Figure 15: Call on the Nettle Creek

Appendix C: Diagram of drought scenario 2

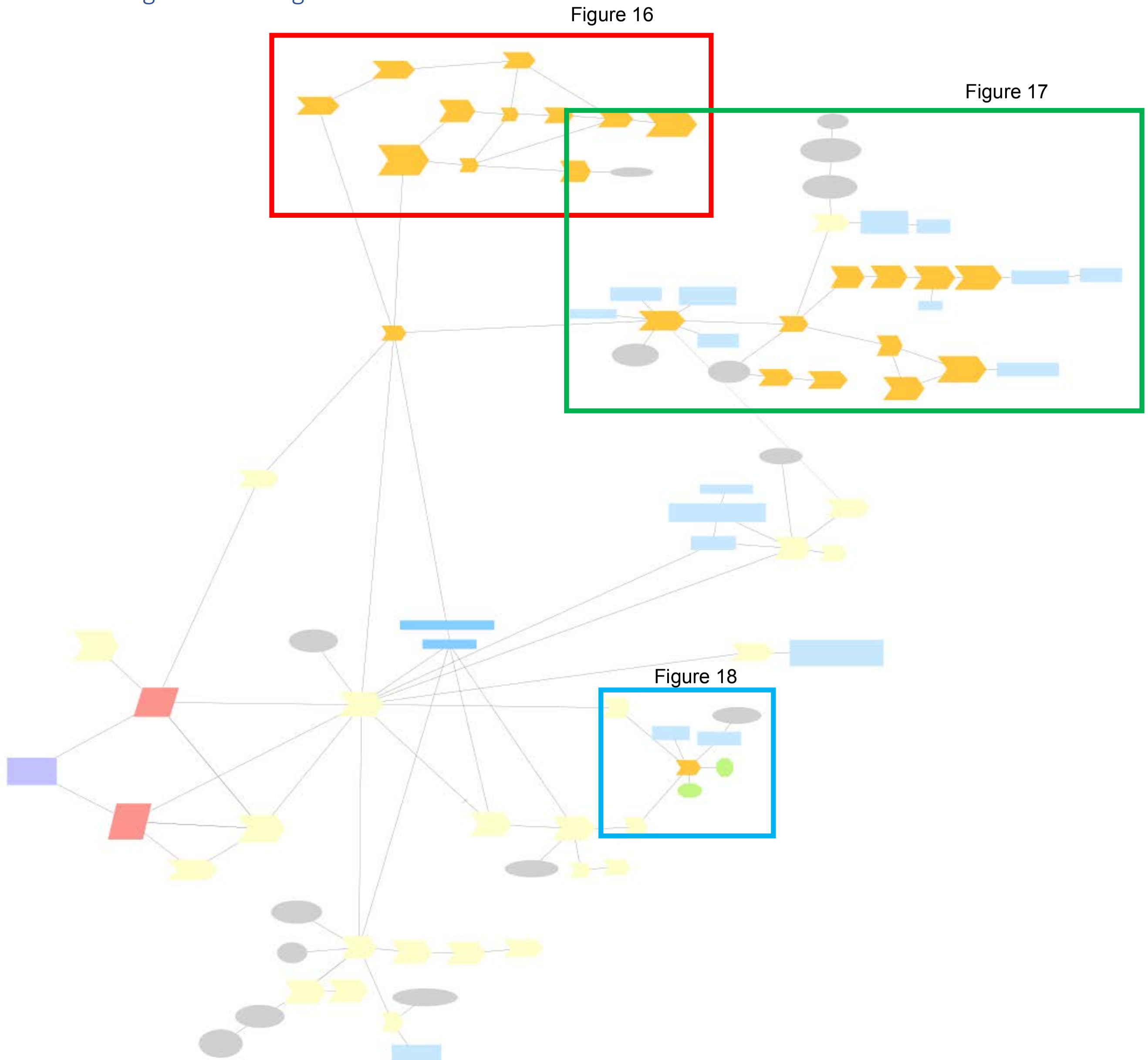

Figure 16: Stress on Ecosystems
Figure 17: Increased Fire Risks
Figure 18: Tourism

Appendix D: Diagramed themes and figures

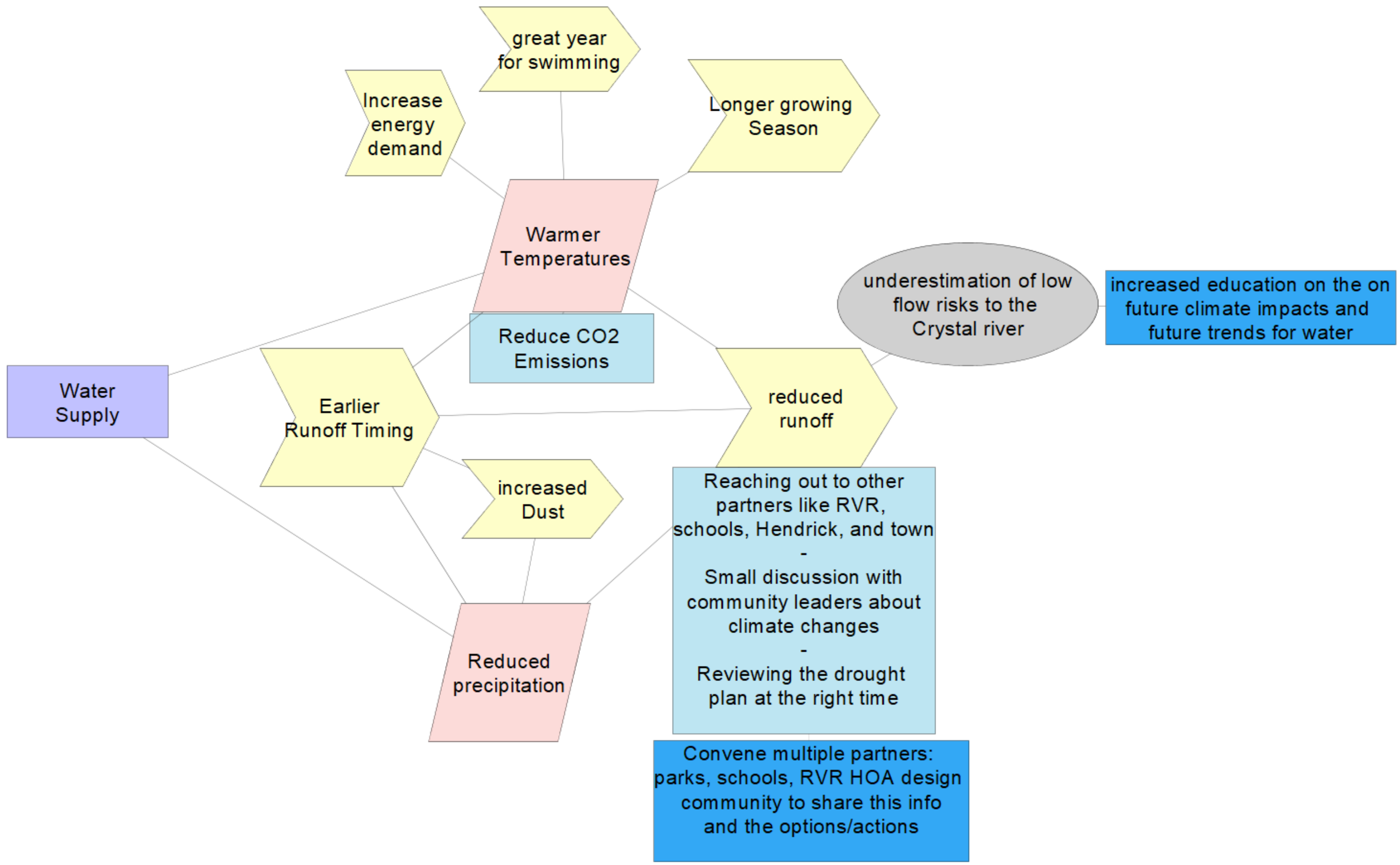

Figure 5: Outcomes, contextual factors and actions linked to reduced runoff. See appendix B for full diagram

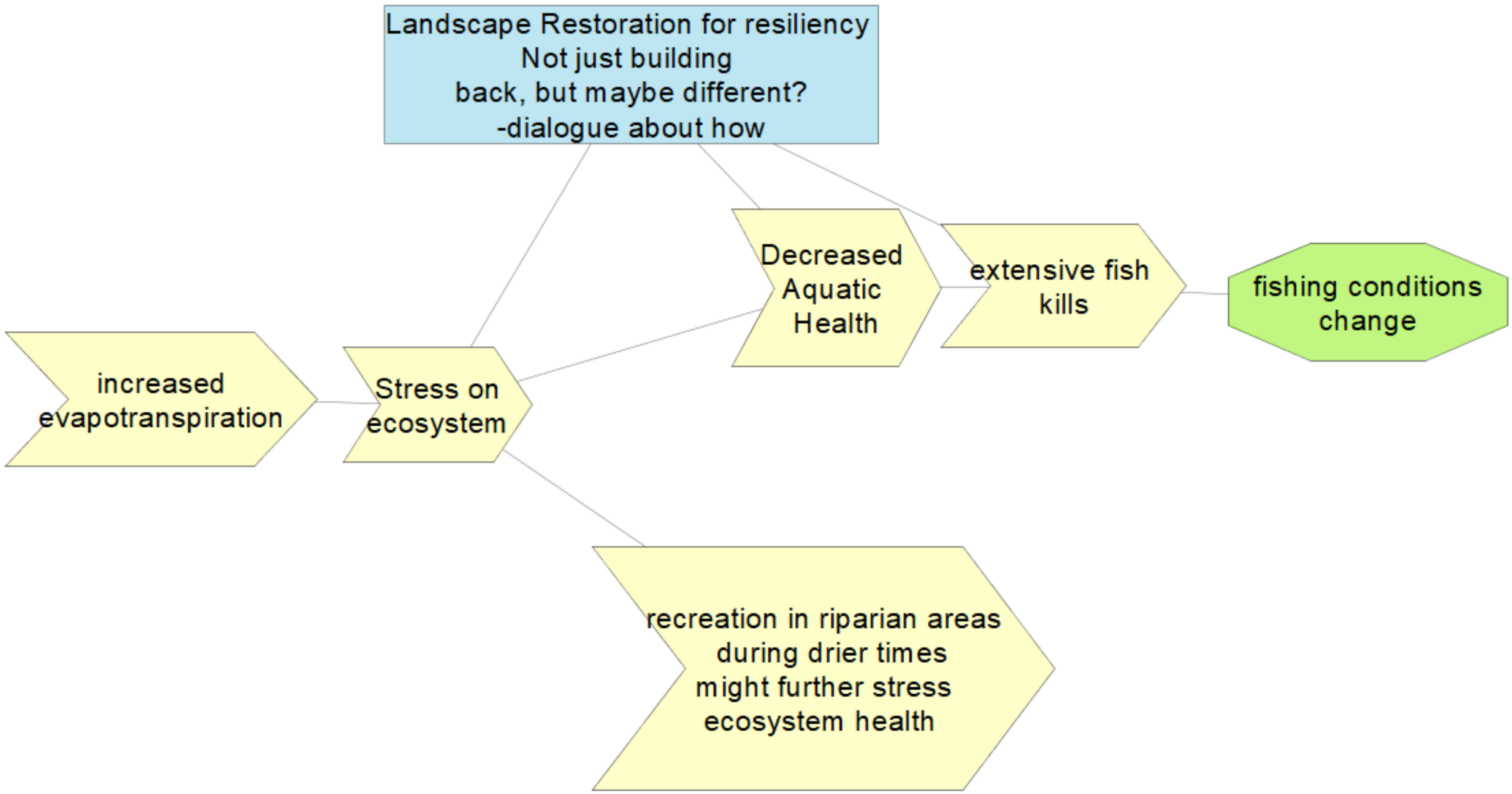

Figure 19: Outcomes, consequences and actions linked to the stress on the ecosystems. See appendix B for full diagram

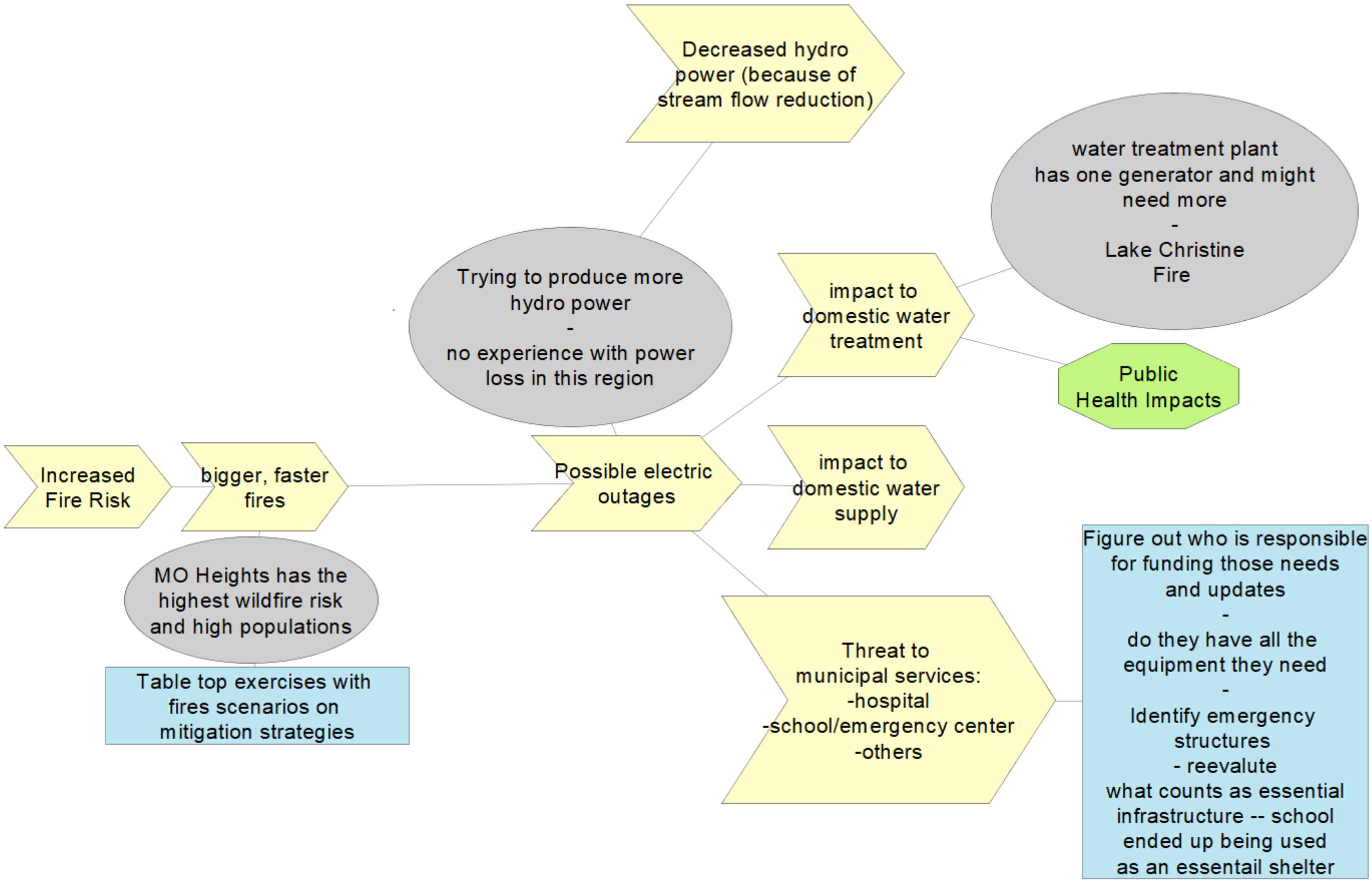

Figure 20: Outcomes, consequences, contextual factors and actions linked to increase in fires frequency. See appendix B for full diagram

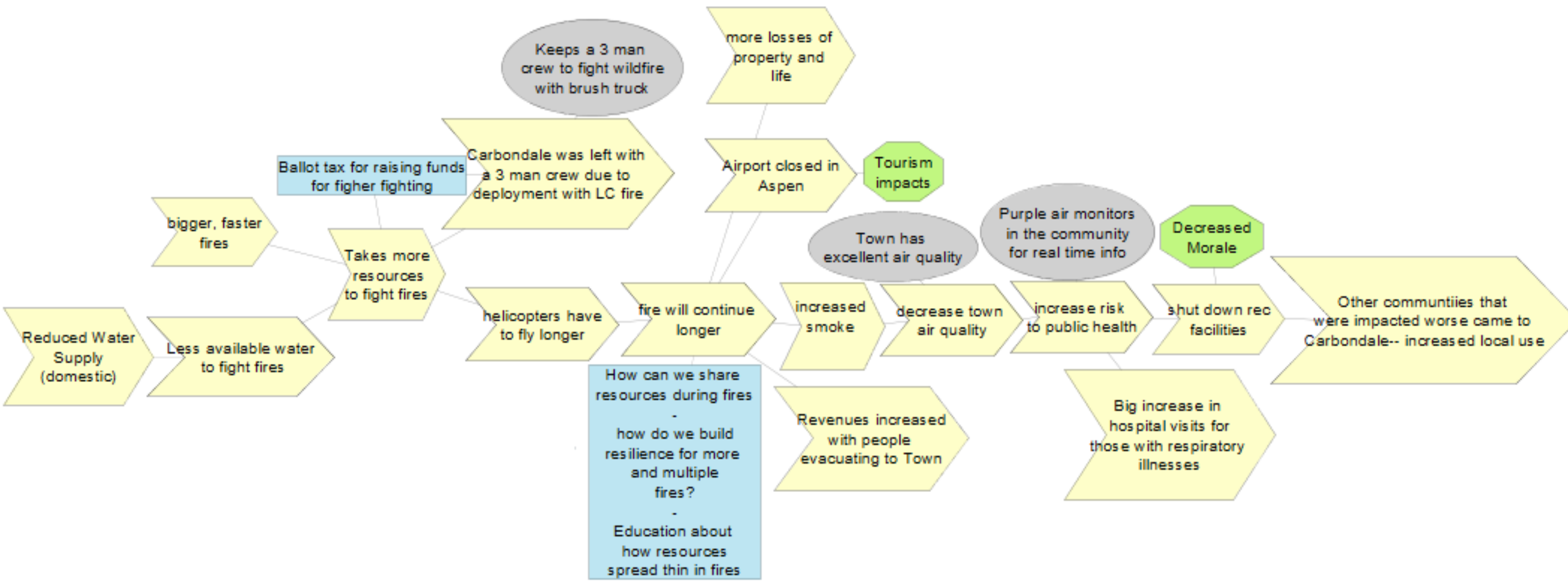

Figure 21: Outcomes, consequences, contextual factors and actions linked to an increase in resources to fight fires. See appendix B for full diagram

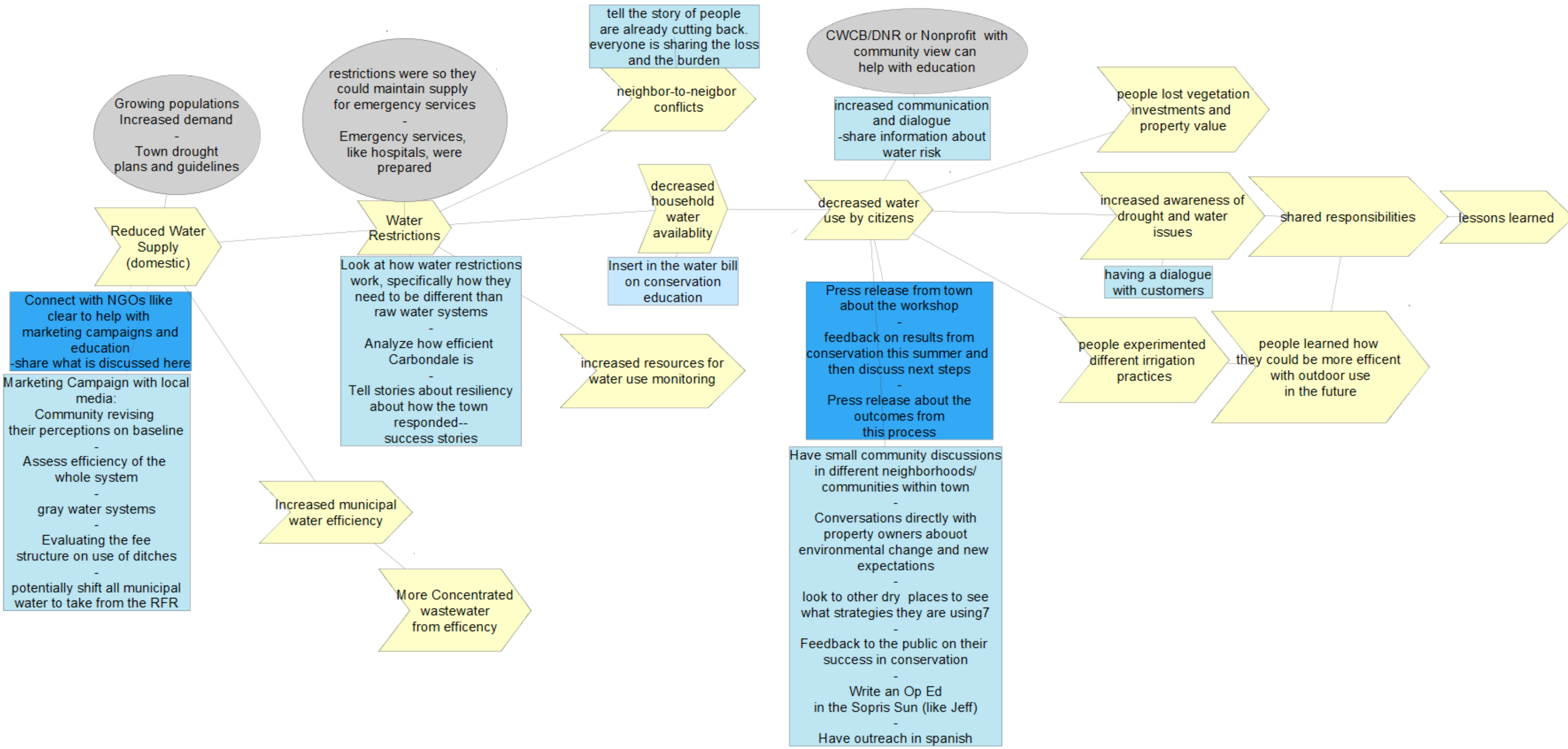

Figure 22: Outcomes, contextual factors and actions linked to a reduction in water supply. See appendix B for full diagram

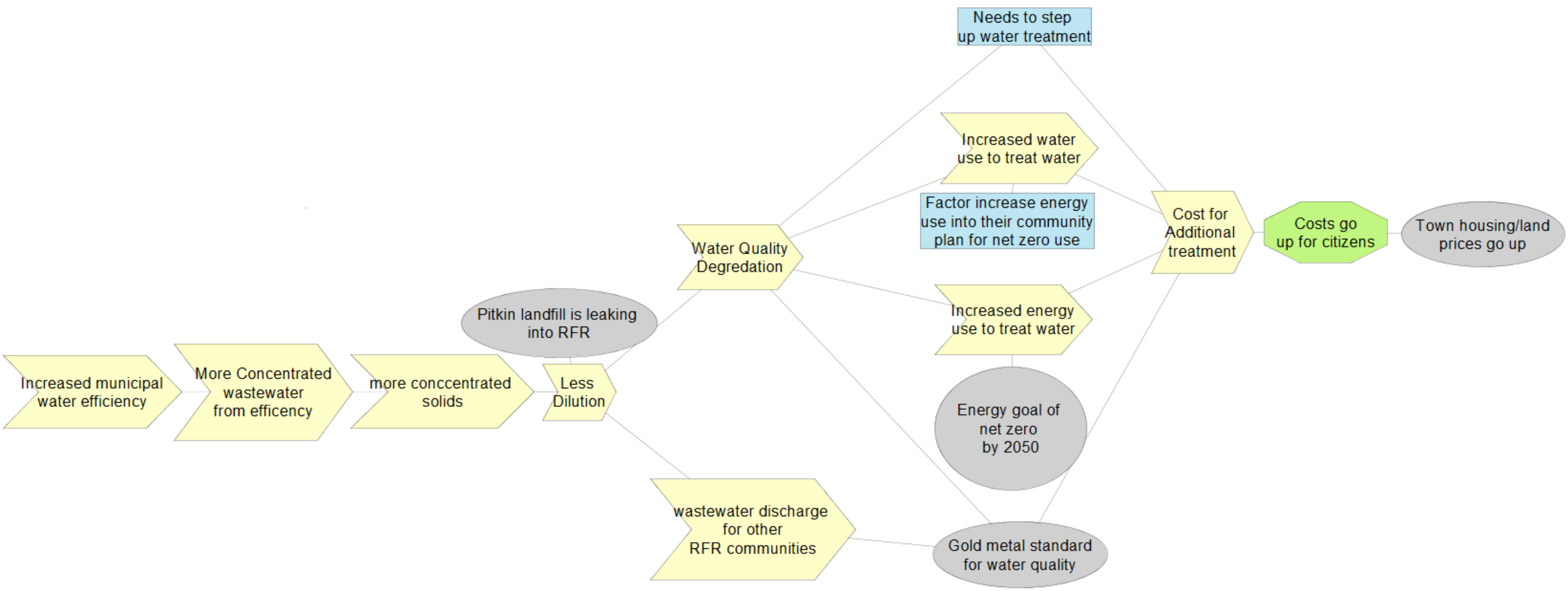

Figure 23: Outcomes, consequences, contextual factors and actions linked more concentrated wastewater solids. See appendix B for full diagram

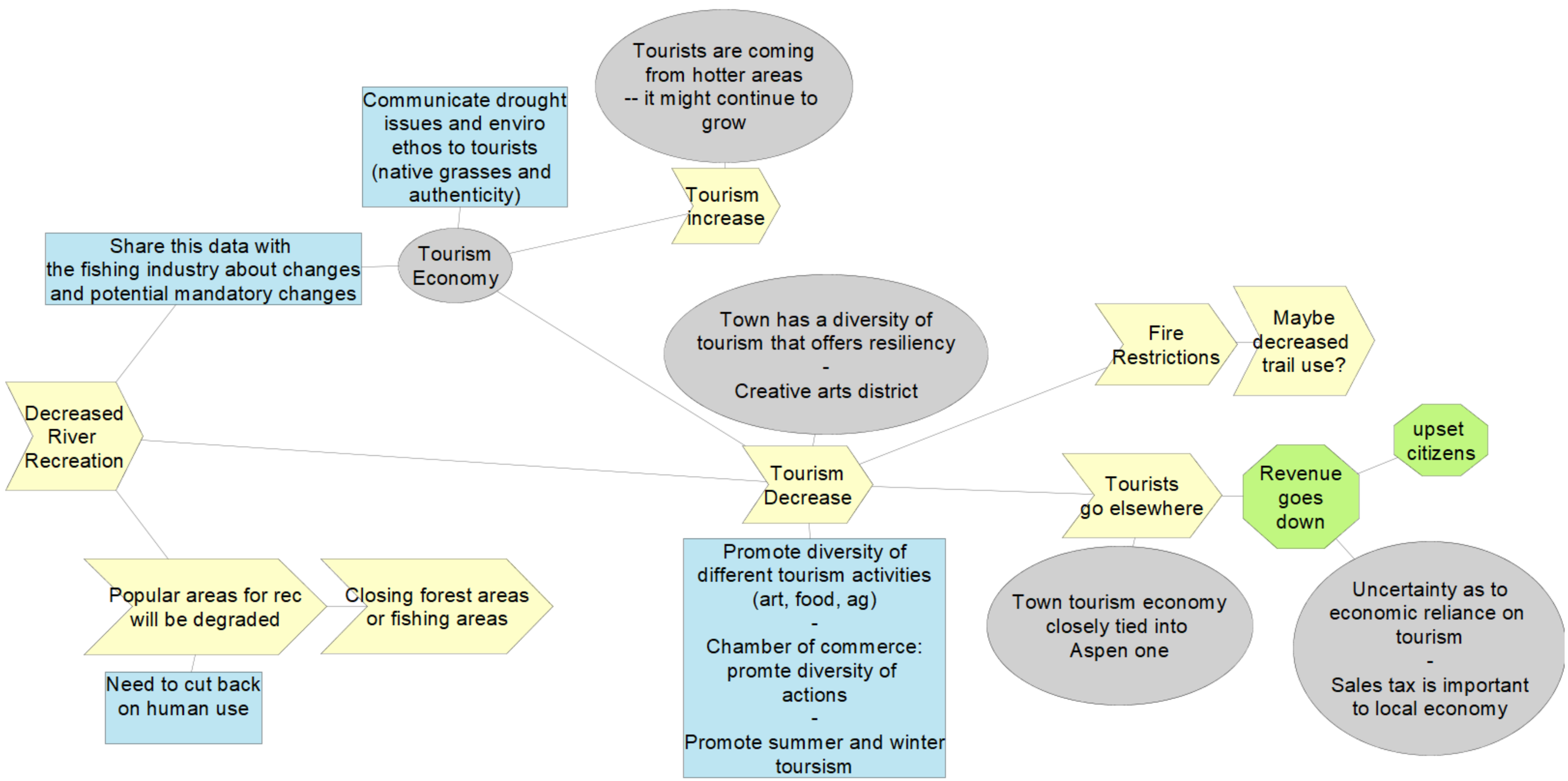

Figure 24: Outcomes, consequences, contextual factors and actions linked to a decrease in tourism. See appendix B for full diagram

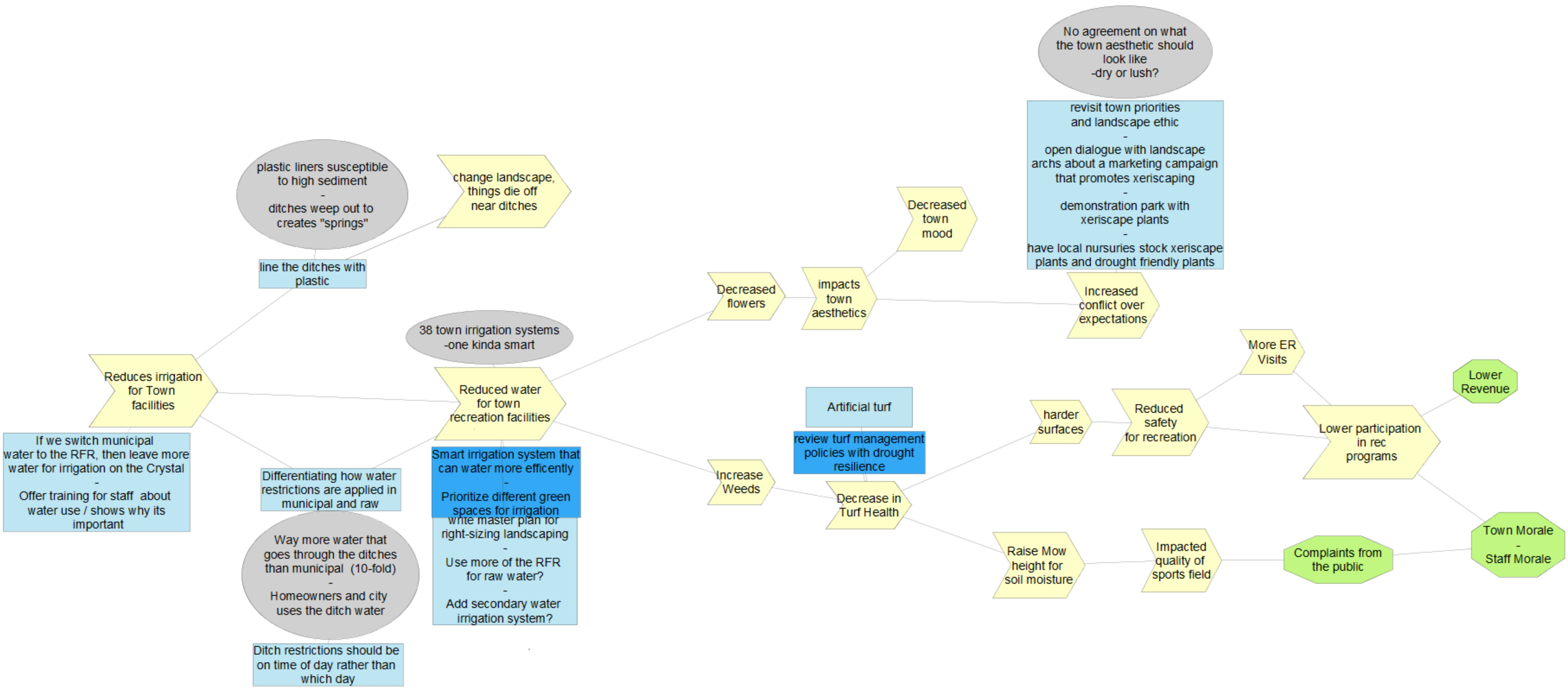

Figure 25: Outcomes, consequences, contextual factors and actions linked to reduce irrigation for town facilities. See appendix B for full diagram

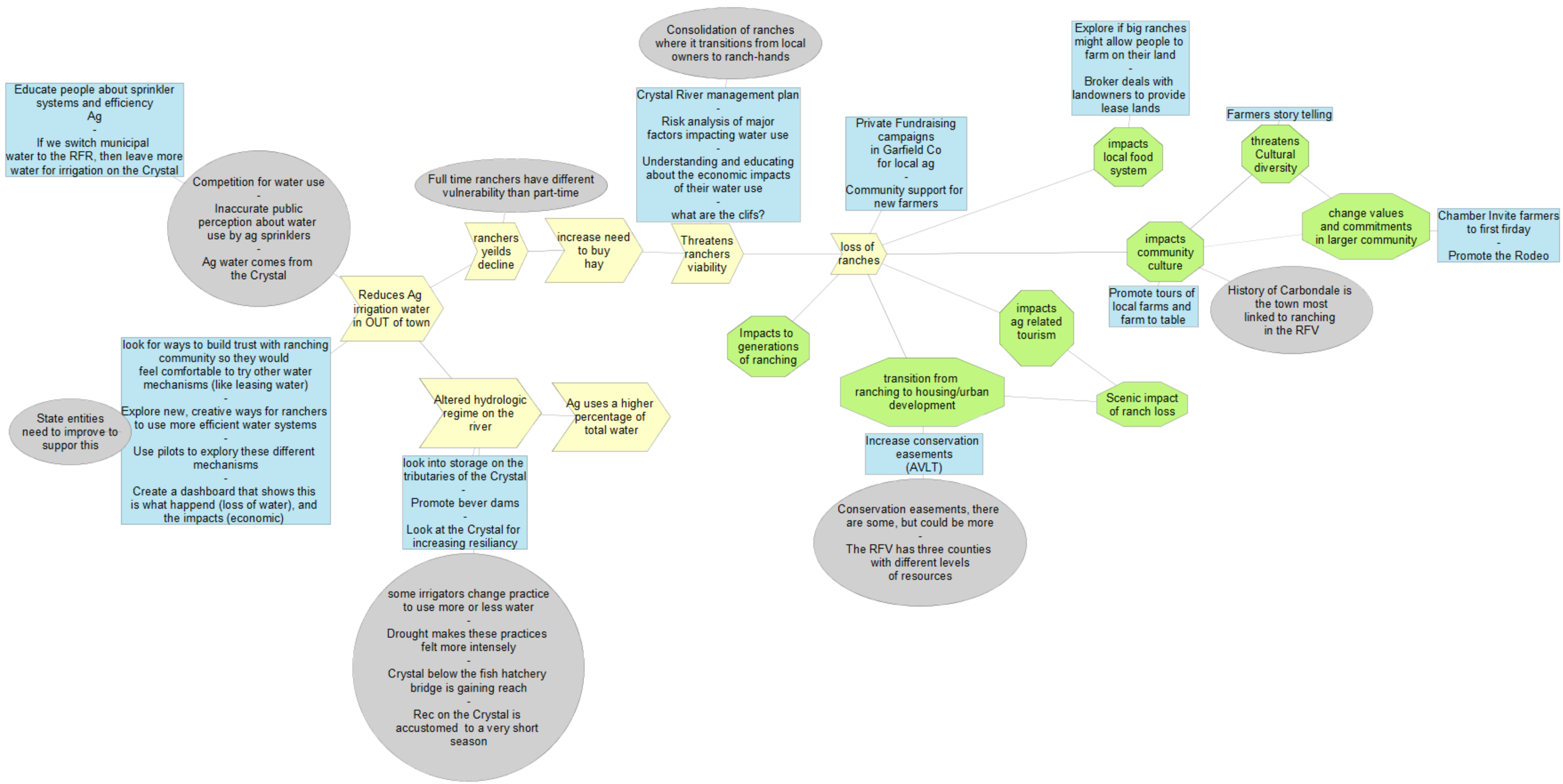

Figure 26: Outcomes, consequences, contextual factors and actions linked to reduced agricultural irrigation out of town. See appendix B for full diagram

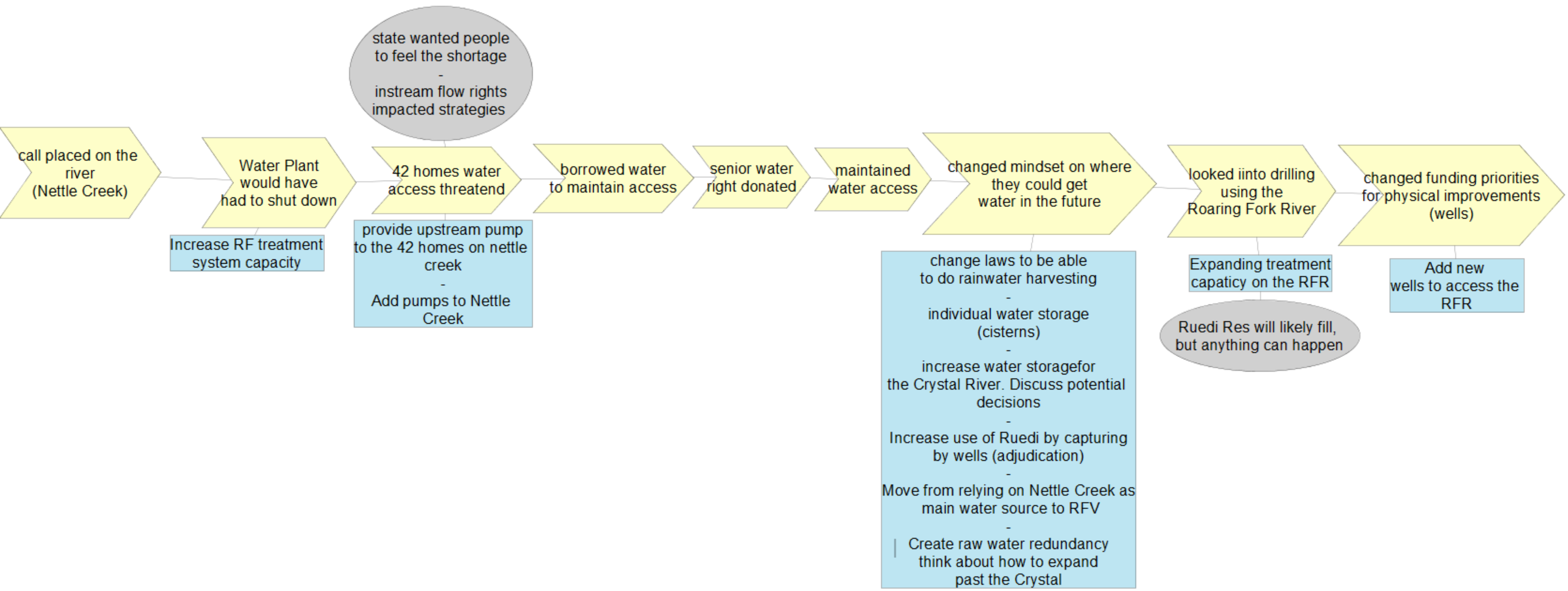

Figure 27: Outcomes, contextual factors and actions linked to a call on the Nettle Creek. See appendix B for full diagram

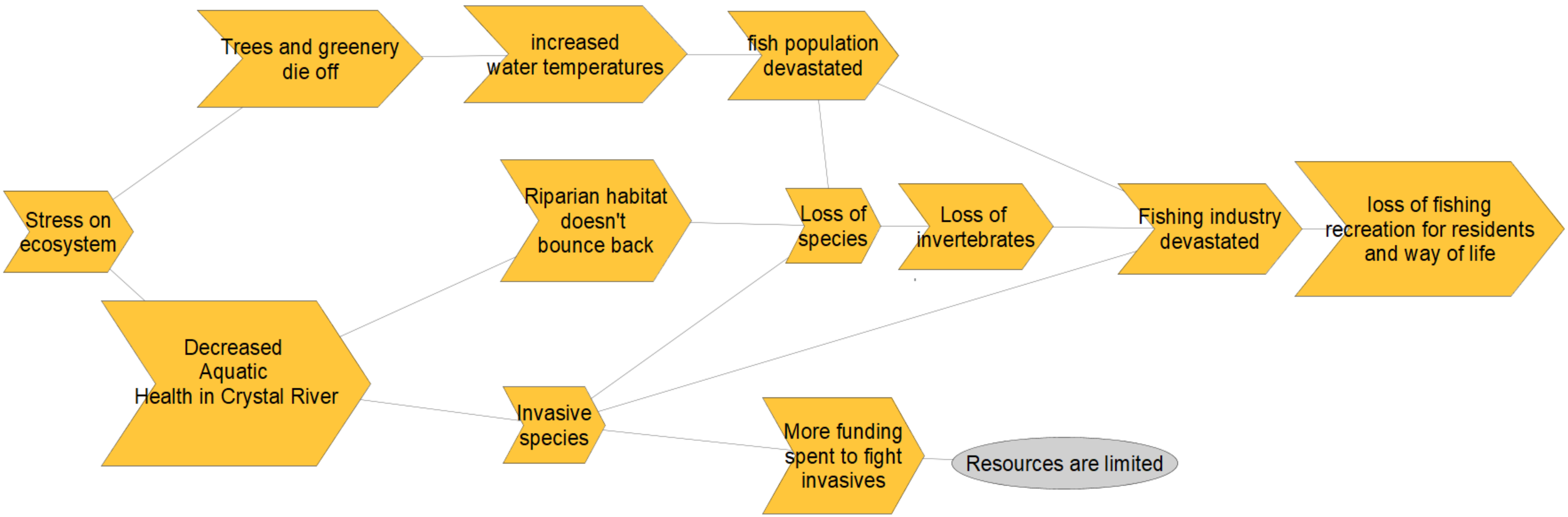

Figure 28: Outcomes and contextual factors linked to an increasing stress on ecosystems. See appendix C for full diagram

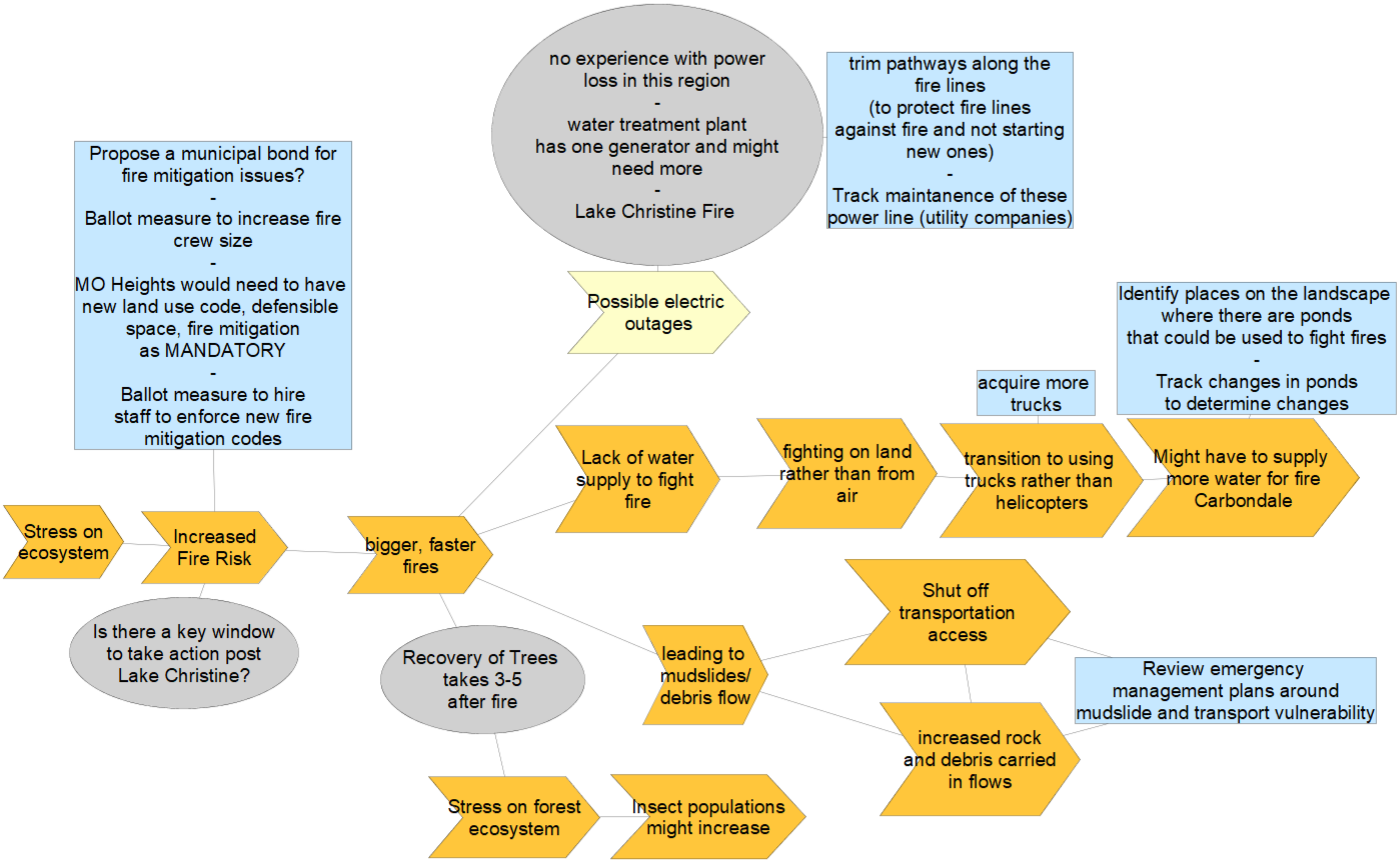

Figure 30: Outcomes, contextual factors and actions linked to an increase in fire risks. See appendix C for full diagram

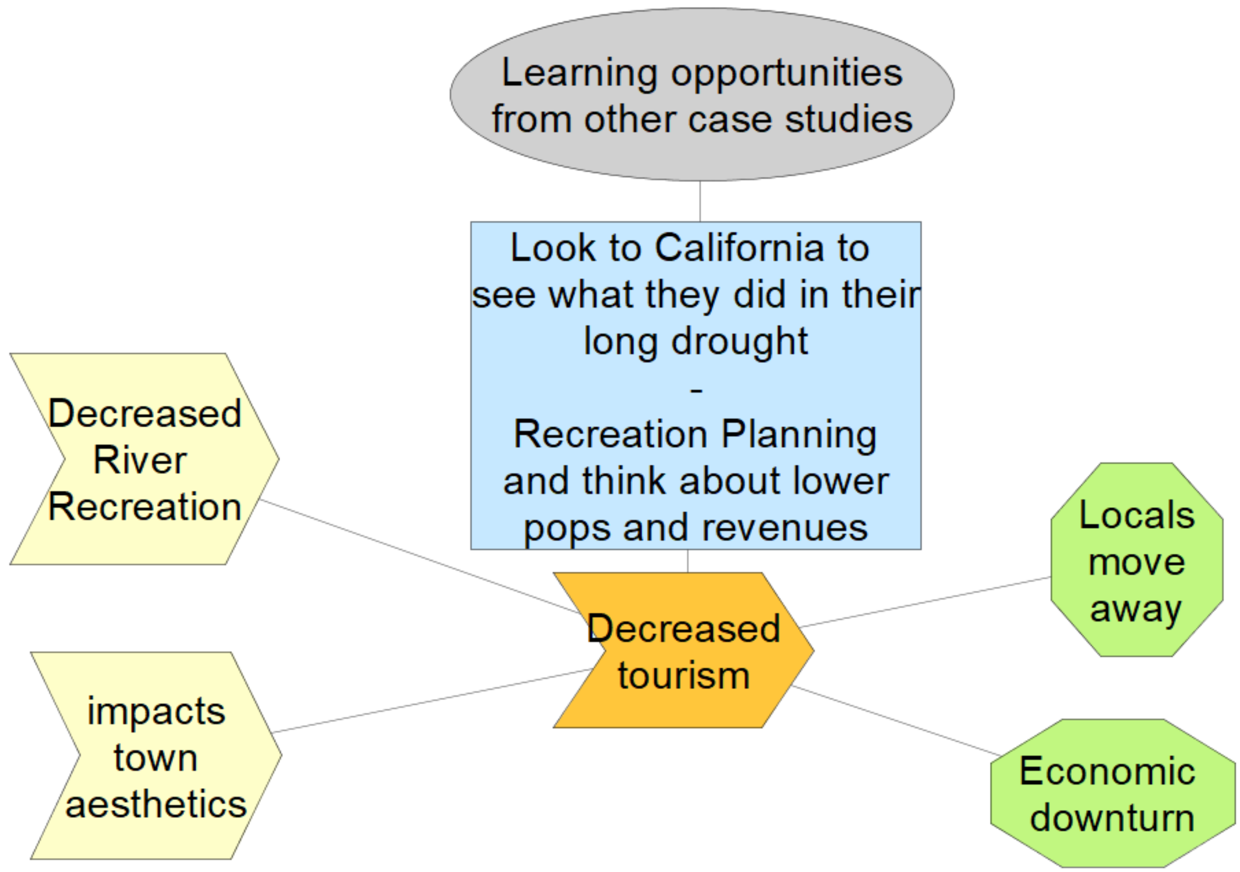

Figure 31: Outcomes, consequences, contextual factors and actions linked to decreased tourism. See appendix C for full diagram